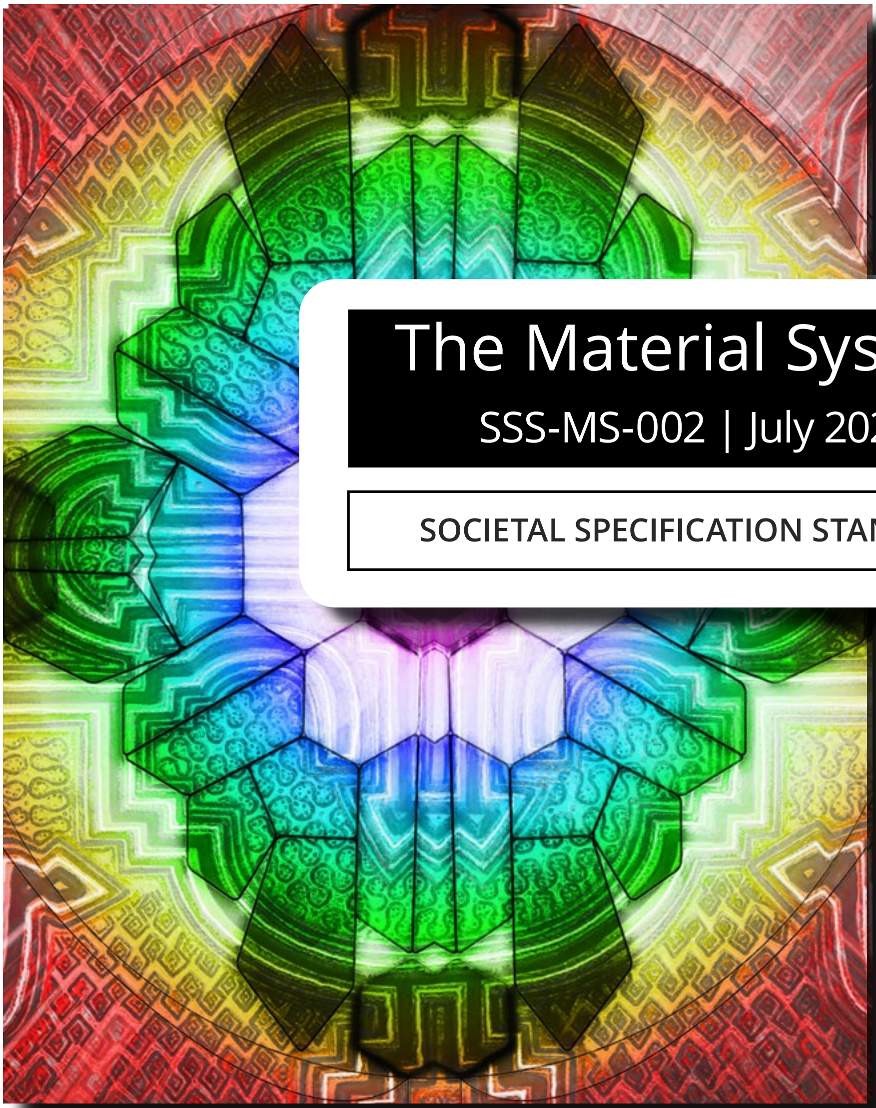
AURAVANA PROJECT

PROJECT FOR A COMMUNITY-TYPE SOCIETY



The Material System

SSS-MS-002 | July 2022

SOCIETAL SPECIFICATION STANDARD

auravana.org

THE AURAVANA PROJECT

SOCIETAL SPECIFICATION STANDARD
THE MATERIAL SYSTEM

Document Reference Identifier: SSS-MS-002

Date of Document Distribution: July 2022

auravana.org

To cite this publication:

- *The Material System.* (2022). Auravana Project, Societal Specification Standard, SSS-MS-002. [auravana.org]

To cite an article in this publication *(authors and article title will change)*:

- Grant, T. (2022). *The Material System Overview*. The Material System. Auravana Project, Societal Specification Standard, SSS-MS-002. [auravana.org]

ISBN: 979-8-9861436-5-1

auravana.org

GREETINGS

In an effort to provide the greatest possible clarity and value the Auravana Project has formatted the system for the proposed society (of the type, 'community') **into a series of standard publications. Each standard is both a component of the total, unified system, as well as intended to be a basis for deep reflective consideration of one's own community, or lack thereof. These formal standards are "living" in that they are continually edited and updated as new information becomes available; the society is not ever established, its design and situational operation exists in an emergent state, for it evolves, as we evolve, necessarily for our survival and flourishing.**

Together, the standards represent a replicable, scalable, and comprehensively "useful" model for the design of a society where all individual human requirements are mutually and optimally fulfilled.

The information contained within these standards represent a potential solution to the issues universally plaguing humankind, and could possibly bring about one of the greatest revolutions in living and learning in our modern time. Change on the scale that is needed can only be realized when people see and experience a better way. The purpose of the Auravana Project is to design, to create, and to sustain a more fulfilling life experience for everyone, by facilitating the realization of a better way of living.

Cooperation and learning are an integral part of what it means to be a conscious individual human. A community-type societal environment has been designed to nurture and support the understanding and experience of this valuable orientation.

The design for a community-type society provides an entirely different way of looking at the nature of life, learning, work, and human interaction. These societal standards seek to maintain an essential alignment with humankind's evolving understandings of itself, combining the world of which humans are a regenerative part, with, the optimal that can be realized for all of humanity, given what is known.

The general vision for this form of society is an urgent one considering the myriad of perceptible global societal crises. Together, we can create the next generation of regenerative and fulfilling living environments. Together, we can create a global societal-level community.

THE UNIFIED SOCIETAL SYSTEM: MATERIAL SPECIFICATION STANDARD

This publication is one of six representing the proposed standard operation of a type of society given the category name, ‘community’ (a community-type society). This document is a specification standard for a material system.

Every society is composed of a set of core systems. Different types of societies have different internal compositions of these systems. The composition of these systems determines the type of society. The type of society described by the Auravana Project societal standard is a, community-type society. The standard is a composition of sub-system standards. The Auravana societal standard may be used to construct and duplicate community at the global level.

For any given society, there are four primary societal sub-systems. Each of these sub-systems can be specified and standardized (described and explained); each sub-system is a standard within a whole societal specification standard. The first four primary standards of the six total standards are: a Social System; a Decision System; a Material System; and a Lifestyle System. Each standard is given the name of its information system. The fifth publication is a Project Plan, and the sixth is an Overview of the whole societal system. Together, these standards are used to classify information about society, identify current and potential configurations, and operate an actual configuration. Because of the size of some of these standards, they may be split into two or more publications.

- **This societal specification standard is the Material System for a community-type societal system.**
- **There are more figures** (and tables) associated with this standard than are presented in this document; those figures that could not fit are freely available via the Auravana Project’s website in full size, and if applicable, color [auravana.org/standards/models]. Tables that are too large to include in this document are referenced with each standard via the Project’s list of standards webpage [auravana.org/standards].
  - *Figures and tables on the website are named according to their placement in the standard.*

Contents

List of figures

This is the list of figures within this document.
There are more figures associated with this standard than are identified in this document; those figures that could not fit are freely available through auravana.org, in full size, and if applicable, color.

List of tables

This is the list of tables within this document.
There are more tables associated with this standard than are identified in this document; those tables that could not fit are freely available via the project's website.

Document revision history

A.k.a., Version history, change log.

This document is updated as new information becomes available.
The following information is used to control and track modifications (transformations, changes) to this document.

VERSION	REVISION DATE	SECTIONS	SUMMARY (DESCRIPTION)
002	July 2022	n/a	The Material System grew so large it had to be separated into two documents, this document and the Habitat System. The Land Assessment is now in a significantly complete form. Various significant additions and modifications have been made throughout. Note: The reader should understand that this document contains a high-level of conceptual linguistic detail, the reader should understand that this document is one of multiple documents that together provide a complete explanation of the proposed societal system. In order to visualize the whole societal system, its concepts and objects, and their interrelationships, must be modeled and reasoned. Note: All figures associated with this standard, many of which are not published herein, are available via the Auravana Project's website. Oversized figures and tables are also published on the Project's website. It is not possible to publish via this page medium all figures and tables related to this standard.

GENERATION ON	NAME	CONTACT DETAIL
July 2022	Travis A. Grant	trvsgrant@gmail.com

The Material System Overview

Travis A. Grant,

Affiliation contacts: *trvsgrant@gmail.com*

Version Accepted: 8 July 2022

Acceptance Event: *Project coordinator acceptance*

Last Working Integration Point: *Project coordinator integration*

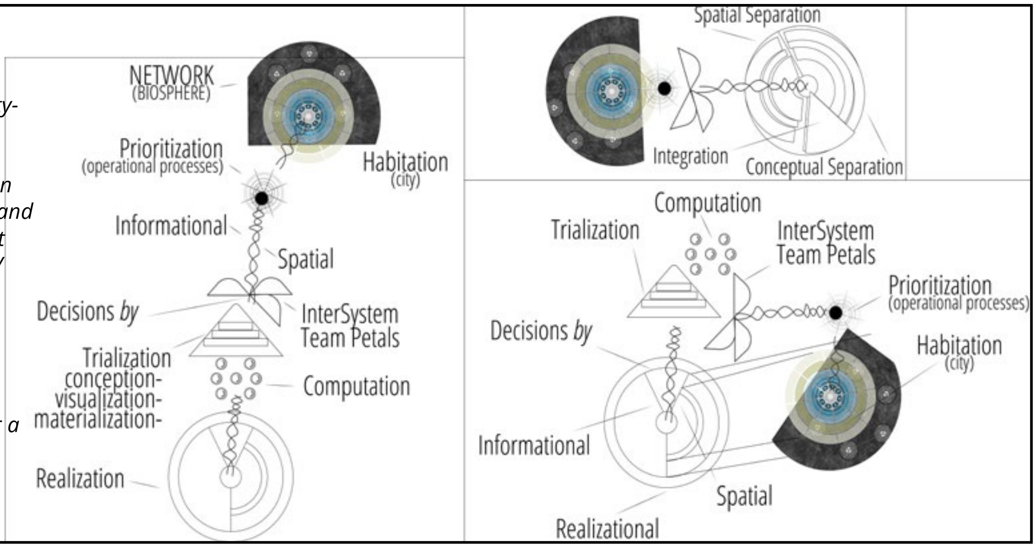
Keywords: material system, physical system, planetary environment, physical environment, material environment, ecological environment, object system, shape system, material control system, material coordination system, material configuration system, physical society

Abstract

This publication is the Material System for a community-type society. A material system describes the organized structuring of a material environment; the material structuring of community. This material system standard identifies the structures, technologies, and other processes constructed and operated in a material environment, and into a planetary ecology. A material system encodes and expresses our resolved decisions. When a decision resolves into action, that action is specified to occur in the material system. Here, behavior influences the environment, and in turn, the environment influences behavior. The coherent integration and open visualization of the material systems is important if creations are to maintain the highest level of fulfillment for all individuals. This standard represents the encoding of decisions into an environment forming lifestyles within a habitat service system. The visualization and simulation of humanity's connected material integrations is essential for maintaining a set of complex, fulfillment-oriented material constructions. As such, the material system details what has been, what is, and what could be constructed [from our information model] into our environment. This specification depicts, through language and symbols, visualization, and simulation, a material environment consisting of a planetary ecology and embedded network of integrated city systems. For anything that is to be constructed in the material system, there is a written part, a drawing part, and a simulation part, which is also how the material system is sub-divided. This standards is a proposal for current material operations and future material organization, based upon what is known about the current physical, material environment.

Graphical Abstract

Figure 18. *Depiction of several views on the realization of a community-type societal information system that cooperatively organizes a mutual human prioritized informational and spatial service system that materializes in a physical/ material environment, primarily in the form of a network of integrated city systems, that collect and serve information and material requirements for a population of humans.*



1 Introduction to the material standard

The visualization and simulation of the interconnected material reality is essential for maintaining a set of complex material constructions designed to remain in alignment with the regeneration of our highest potential state of fulfillment (i.e., our highest potentially expressed fulfillment or HPEF). In a material context, our HPEF is determined by how efficiently we re-configure the resources in our environment into services which are effective for fulfilling human needs and maintaining individuals' access to opportunities for discovery and growth.

The Material System describes what has been, what is, and what could be constructed [from the society's information model] into its material environment, and therein, a global human habitat. In other words, it is a description of what has been materialized (past material state), could be materialized (future potential material state), and what is, materializing (current operating state). It depicts the selectively materialized expression of the society's information model as well as all probable alternatives. Essentially, this is a standard for the material domain of a society. Simply, it contains all information about the material nature of society; it describes the part of the community [information] system that is, was, or could be operational at the material level. This standard addresses the materially constructed system through knowledge and tools into processes and services that combine to form technologies which function to provide resource flows and material transformations for human fulfillment.

This standard accounts for the localized placement of all material resources within the biosphere and local habitat service systems. It accounts for not only resources, but also for the material reconstruction of the common environment through integrated access to common [heritage] resources via a unified information model, one phase of which represents the product of the interaction of the other three systems, the materialization of a service system (i.e., the after decisioning comes material reconfiguration, which humans then live within for some duration of time).

This standard depicts through written word, visualization, and simulation the materialization of an integrated habitat service system, which is more commonly referred to as a total city system network. The habitat service system is the material, technical system which facilitates the fulfillment of identified human needs. The material system is a planned. The cities herein are connected and integrated into a network of cities forming a complex human community contributing to and utilizing a unified information model and a global material access system.

NOTE: *A 'material specification' is the expression of a set of materializing relationships.*

Humans experiences their constructions, and so, in community, humans socially organize and plan for their constructions. This is accomplished through the social collection of information, which is feed into an shared decision space, which is transparently resolved into a re-configuration of the common material reality. Generally, that re-configuration takes the form of a circular walking-garden city system composed into a distributed network of cities operating together and based upon the same information model.

The integrated city system is a controlled service space where our built world mimics and harmonizes with the regenerability principles of the natural world. If we flow with natural principles we can even amplify what we are capable of in nature; we can get even better at it, and do it in a way that keeps us harmonious with the natural world, so that we aren't fighting the flow. And herein, we structure our lives and environment so that we naturally do things that are fulfilling

In community, our evolutionary impulse gives rise to the dialectic of "progress" expressed through continuous improvement within an ecological environment, rather than continuous expansion of a made up number that a bunch of people are telling themselves a story about (i.e., "GDP"). Community accounts for that which exists, and by letting go of [artificial] narratives it can optimize therein. In the Community, technology's ability to generate abundance is fully utilized without the restrictions of an economic system that values, and thus, manufactures scarcity. In community, the capacity to automate rote tasks is fully utilized, freeing humans from tedious jobs in an economic system where they are no longer needed. Technology is embraced, not as a solution in itself, but as an extension of our abilities and power, which will be as constructive as our value systems is inclusive.

1.1 Material construction

The Material Specification represents the convergence of information and matter into physical construction. In order to socially construct something into the material environment of the community [at least] three principal elements are required: a written explanation; line drawings; instrumentation and measurement. Each of these three elements is essentially a different viewport (i.e., a different window) into the same information model. We are capable of expressing our perceptions of reality via multiple mediums, such as written language, visualizations, and through ordering. When this information is combined into a single package, which can be understood by a receiving entity, then the systems design is replicable, and can be duplicated given the availability of resources.

When we encode our concepts into material structure they begin to take up space around us, which become the very constructions we live in and spend most of our lives around. From this perspective, the material specification provides descriptive reasoning for why we have constructed that which we experience as our constructions in an environment, and how to reconstruct our constructions given what is known and what is available.

In order for something to be materially constructed in community we have to know:

- Why we are constructing.
- What we are constructing.
- How we are constructing.
- The alternative ways and configurations we could be constructing.
- And, how to replicate our current and past constructions.

In other words, the written part is our description and logical reasoning for the system as it could be, as well as the system as it presently exists in its current state of operation. Importantly, it includes instructions on how to construct different versions of the city. It also describes to the constructor/builder how to build the material design for the community.

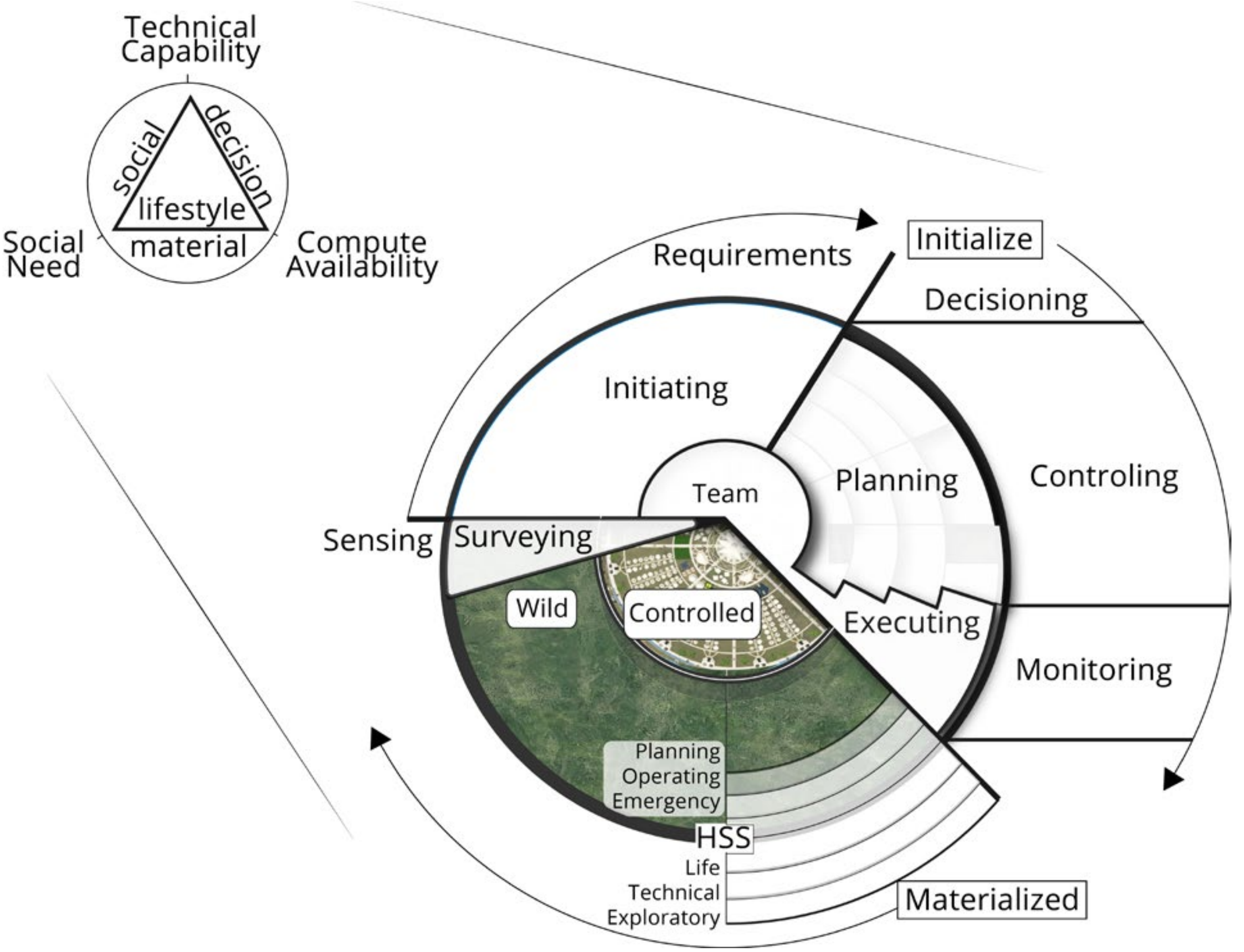
2 The material specification standard sub-composition

The material system subcomposition:

1. The written documentation part.
2. The architectural CAD- and BIM-based drawings for the integrated city system.
3. Database of materials and their properties, and technologies
4. The 3D visually modeled and simulated representation of the integrated city system.
5. Integration of the 3D representation into a gaming engine for virtually simulating all technical operational aspects of the community.

A material system describes the material blocks/ patterns that we have to work with and the optimal configuration of those patterns to sustain and evolve our fulfillment.

Figure 19. *The real-world community model executing [by means of teams and objects] the realization of a network of habitat services systems within a larger planetary ecology where humans have needs (real world requirements) that can be met with some level of knowledge and understanding.*



Material system documentation shall indicate, at a minimum, the following:

1. A description of the system functions, or a functional diagram.
2. Specifications of systems and their location (if available)
3. Type of materials
4. Type of technologies and requirements for their installation

In the sense that any given material environment can be interfaced with, there are seven primary relationships:

1. Identification: concepts & naming [conceptualizing and naming]
2. Location[ing]: positioning between objects.
3. Design[ing]: construction of an object.
4. Services[ing]: constructing the motion of multiple objects to serve a function.
5. Structure[ing]: the integration of multiple objects in motion.
6. Account[ing for] Materials: the composition of any given object.
7. Account[ing for] Technological modules (a.k.a., technological infrastructural modules): the construction and integration of multiple objects to serve a usage.
8. Account[ing for] Human requirements: the needs and preferences of the human users.

In the sense that any given material environment can have any of four primary gestalts:

1. Structures (objects on land or crafts in mediums)
2. Subjects (people or people-like organisms)
3. Energetics (motion, electromagnetics)
4. Terrain (planets and human re-contoured land)
5. Devices (functional objects in structures or on land for specific temporary and/or mobile use; a.k.a., tool, non-structure usable item; a consumable may, or may not, be considered a device)

2.1 Material specification components

There are four principal parts to the specification for the materialization of the Community.

1. Specifications - the written documentation part. A specification set may also include the drawings for the set.
2. Drawings - the graphical presentation of that which is to be constructed. Drawings are intended to depict the general configuration and layout of a design, including its size, shape, and dimensions. It informs the constructing entity of the quantities of materials needed, their placement, and their general relationship to each other. Although drawings may contain all the information about a structure that can be presented graphically, they nevertheless omit information that the contractor must have, but which is not adaptable to graphic presentation. Information in this category includes quality-related criteria for materials, specified standards of workmanship, prescribed construction methods, etc. There should be no discrepancies between drawings and written specifications.

2.2 What is a master specification?

A “master specification” is a template document that must be used and/or edited to execute (and/or operate) a specific project (and/or system). In other words, a master specification contains sufficient information that it can be used to complete a specific projects. Master specifications are also referred to when modifications are implemented to fit particular conditions of a given job or new specifications are incorporated.

> **NOTE:** *The Auravana Project’s societal specification standard is a master specification [standard].*

In concern to a master construction specification, for example, the master may contain a list of index numbers, characteristics, specifications, units of measure, and additional information that is to be used for specific material projects.

2.3 Specifications

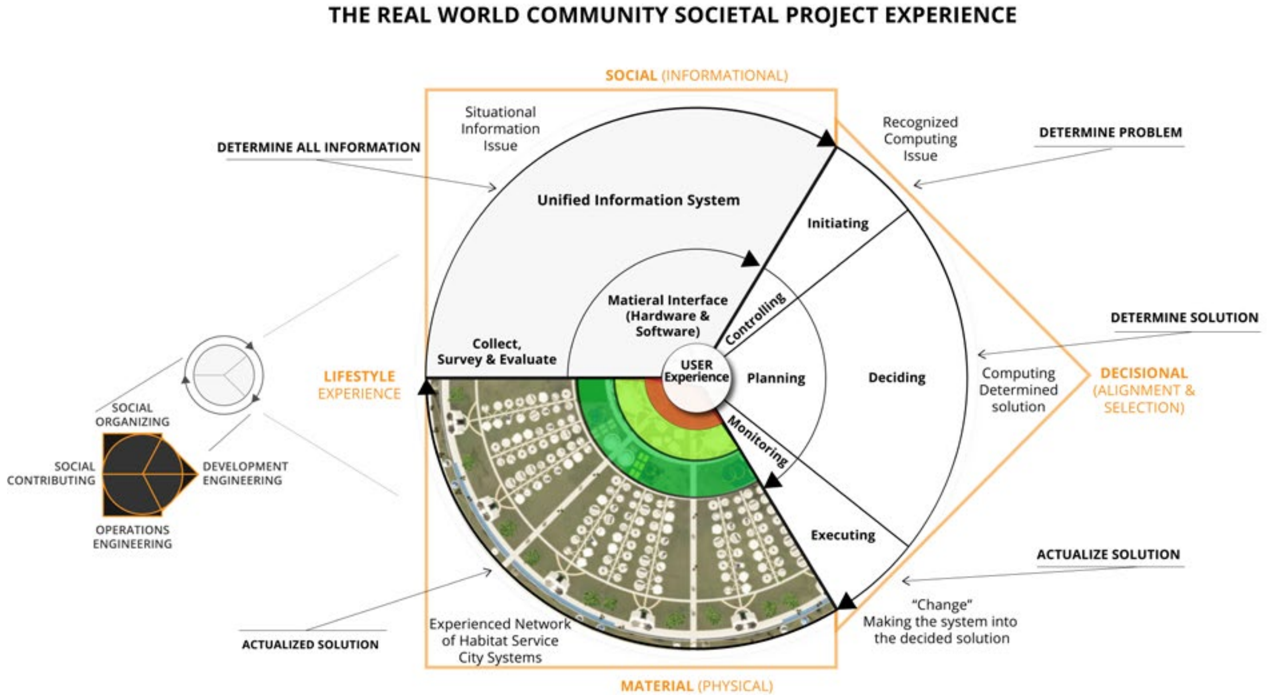
The word specification merely refers to the act of “to state explicitly or in detail” or “to be specific”. There are many different types of specification. Sometimes, a “specification” is a written technical descriptions of a design, which may be contrasted with a “drawing”, which is a visual depiction of a design. However, here, the total description of a design is called a “specification”. Anything that is to be constructed must involve a specification. If it is needed in order to understand, construct, operate, or take down, then it is a component of a specification. A specification may also refer to a type of technical standard. In a way, these specifications represent the technical standard for community.

Note: From the commercial perspective, specifications are “that portion of the Contract Documents consisting of the written requirements for materials, equipment, systems, standards and workmanship for the Work, and performance of related services.”

All specifications for the material system, including the material system itself, involve written language, symbols, drawings, and simulations. These are separated into “parts” of a specification. For anything that is to be constructed in the material system, there is a written part, a drawings part, and a simulation part, which is also how the materials system specification is itself divided. Symbols are likely to be used throughout. Here we may refer to the part of the specification which is written as "the written part of the specification", or "the written specification". The written part uses verbal language: the language of reasoning (verbal reasoning) and science (scientific evidence) to describe why the system is so constructed; and, technical language describing materials, equipment, systems standards, workmanship for the work, performance measures, and performance of related services; and engineering language to describe how it is so constructed, including composition, creation, assembly, and disassembly (as well as [re]-cycling). Visual specifications include those which are represented as [technical] drawings (i.e., drawing specifications or the drawing part) and simulations (i.e., simulation specifications or the simulation part). A technical drawing precisely and visually communicates how something functions or is to be [de-]constructed. Technical drawings are understood to have one intended meaning (i.e., they are not interpretable in more than one way) -- they use visual language to ensure they are not ambiguous and relatively easy to understand. Drawings are made according to a set of conventions, which include particular views (floor plan, section etc.), sheet sizes, units of measurement and scales, annotation and cross referencing. Herein, all architectural drawings, mechanical or other sketches, and CAD drawing applications are considered [technical] drawings. A simulation, however, is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time. Any object (i.e., "material thing") which is to be, or has been, constructed is described within a specification that includes all three parts.

Using the word "specification" without additional information to what kind of specification you refer to is confusing and considered bad practice within systems engineering. Hence, it is important to state that when we refer to the "design specifications", what we are referring to is the comprehensive specification for

Figure 20. *This is a project to build a unified type of society where the total environment is recognized as necessary for computing a re-organization of the material environment where humans exist and persist in accordance with their behaviors, their creations, and the larger cosmic dimensional sphere. There is a material existence to human consciousness that can be physically interfaced with through human behavior (or, more precisely, an individualized consciousness behaving as a human among others similarly behaving. It is possible to orient and re-orient the materially structured environment where all humans behave together. It is possible to decide and design together a global platform composed of a network of integrated city systems where human individuals are fulfilled through the realization of a specific configuration of a socio-technical environment (i.e., a specific configuration of a material, physical environment; a specific societal object configuration environment). By planning these societal environments based upon the integration of a total information environment, it is possible to optimize material creation (Read: the material dimension of the human experience) for all of humankind and the ecological system upon which it exists.*



the total community system, which may be called the “Community System Specification”. It is the core/kernel specification.

Specifications are mean to integrate and connect with one another. Specifications are meant to be operated and then retired or updated. The architectural construction industry organizes its specifications into divisions and levels.

> **QUESTION:** *A specification is a formalized design. Hence, the word "design" may be considered superfluous before the word specification.*

2.4 Individual technical product sheets

See addendum for individual technical product sheets, which include:

1. An individual product specification sheet.
2. A product sub-system operating parameters.

2.5 Material processes

A.k.a., Material dynamics.

There are many examples of material dynamics, including, but not limited to:

1. Biospheric/ecological dynamics
2. Water & atmospheric dynamics
3. Energy dynamics
4. Chemical dynamics
5. Structural dynamics

All systems (power systems) have resource [depletion] impacts and environmental impacts.

2.6 Material objects

Material components are the building “blocks” for creating a material system. No two or more objects can occupy the same space (spatial scarcity) at the same time (temporal scarcity).

2.7 Space control through space-time separation

In community, the population plans for well-being. A population create a setting that is conducive to better flow and better use. Here, spaces with different lifestyle-functions that could conflict are separated by time and/or space. For example, space for noisy social interaction is separated from quiet space. Not only does this separation facilitate natural movement between spaces with different lifestyle- and system-oriented functions, but it reduces disturbance for those using particular spaces with set functions.

2.7.1 Material Optimization

Human constructions become a part of the human environment. A body naturally become adapted (e.g., optimized) to its given environment. When individuals optimize the environment for our fulfillment we facilitate the experience of optimum fulfillment. It is wise to create material structures that facilitate the alignment of our behaviors with our explicit desire (i.e., intention) for purpose, potential, and play.

2.8 Economic planning and habitat elaboration

An economic plan requires an elaborate description of each habitat service subsystem. These descriptions are required in order to develop a complete input-output matrix for a habitat economic service system.

A Habitat Service System for a Community-Type Society

Travis A. Grant,

Affiliation contacts: *trvsgrant@gmail.com*

Version Accepted: 8 July 2022

Acceptance Event: *Project coordinator acceptance*

Last Working Integration Point: *Project coordinator integration*

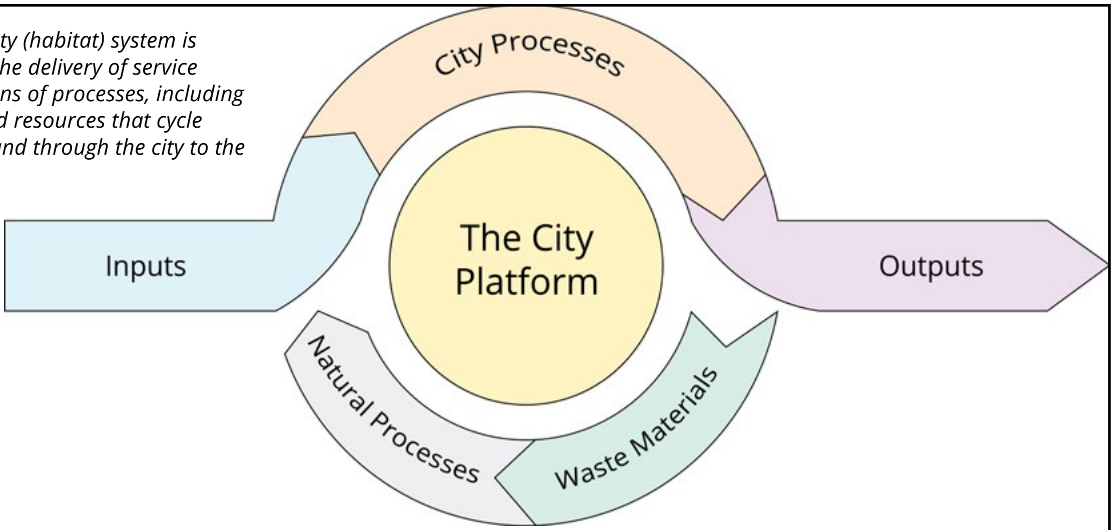
Keywords: city, city system, habitat service system, life radius, village system, cybernetic city, cybernetic habitat

Abstract

A city (habitat) in a community-type society is an integrated, total living environmental service system. Another name for a city is a habitat service system. Cities in community are the result of viewing society first and foremost as an information system, from which cities are designed, developed, operated and adapted. A city represents an individual's generalized life radius and the localization of services. Community-cities are humanity's primary habitat within the larger planetary ecology. These cities form a unified cooperative network for the sharing of information and resources to maximize global fulfillment of access.

Graphical Abstract

Figure 21. *A city (habitat) system is a platform for the delivery of service outputs by means of processes, including information and resources that cycle within the city and through the city to the larger ecology.*



1 Introduction

A.k.a., The habitat service system.

The technical term for a 'city' is a 'habitat service system' - a service system integrated into a larger ecological/planetary habitat. The city is a central concept for human population-scale living. Every city is a continuous process of material creation, usage, and re-configuration. Therein, the rise of city networks and the movement of humanity into a predominantly engineered environment corresponds to a broader process of change during the "anthropocene" (the age of humans).

TERMINOLOGY: *Habitation (noun) the state or process of living in a particular place; a dwelling or city in which to live.*

In common discourse, the word "city" carries several characteristics, each portraying a different perspective on life in a materialized socio-economic system. The term, "city", is characterized differently depending upon societal perspective. From the perspective of population scale, people come together to form service hubs which are often given different names depending on the specific population size of the service hub. The population scale is generally something equivalent to: tribe [smallest population] hamlet > village > town > suburb > city > megacity (metropolis or megalopolis) [largest population]. In community, however, there is a global, unified habitat service system [network] in which there are many interconnected smaller habitat service systems known commonly as 'cities', each of which has been designed with a carrying capacity set by its [designed] configuration. To some extent, these other terms (e.g., village, town, etc.) for what is essentially a service system hub integrated into a habitat, divert attention from that fact. In other words, because of the language around how humanity is fulfilled, people don't generally think about a "village" or "city" in terms of what it actually is; which is, the materialization of socio-economic information into the material environment in the form of a habitat service system that exist to service human fulfillment requirements.

From a 21st century perspective on resource sustainability, a city is a place that requires that the majority of resources and goods come from outside of its boundary (i.e., it is, fundamentally, an unsustainable structure). Conversely, in community, the habitat service system must by definition be sustainable. It must be sustainable, because the term itself indicates the presence of a service system within a habitat, and for a habitat to sustain the population it must not overshoot carrying capacity. A habitat is a place where material needs are regeneratively fulfilled. If a habitat service system cannot sustain itself with local resources or sustainable access to the global network of resources, then it will assuredly begin to degrade and should not be considered a habitat service system. In community, the term 'habitat service system' is just another word for a "city", but the city is sustainable.

From the perspective of authority, a city is a governed area with a leader (or leadership) of some kind. Therein, a city as a space of government and authority, the territorialization of government through the structuring of social networks based upon power-over-others relationships. The city is a place where discipline and subordination is imposed. In contrast, in community, there is no authority who governs or otherwise leads everyone, or anyone. Instead, there is a common information model, an accountable decision process, and a contribution structure that facilitates participation in ones own life and the lives of all others.

In many jurisdictions (i.e., "States") cities are legally defined by their status of incorporation. City status is thought to be a natural progression to further raise the competing population's economic profile. A city, like everything else in the market, is a product to be bought and sold. The most well-known city products are Paris, Beijing, Moscow, London, and New York. Aside from marketing to get people to understand and participate in community, marketing is not a part of the socio-economic process for any city within the community network.

A city could be viewed as a piloted system, and equated with the modular nature of a space station. Cities could be designed like modular space stations, highly flexible and highly sustainable. A space station, like a habitat service system, has modular life (and other) support functions. Thus, in a more abstract sense, the core platform of a habitat service system could possibly be viewed as a "spacecraft bus", which is a major part of the structural subsystem of a spacecraft. It provides a place to attach components internally and externally, and to house modules. The bus also establishes the basic geometry of the spacecraft, and it provides the attachment points for appendages such as conduits (e.g., booms), communications elements (e.g., antennas), and sensors. Similarly, a city is a platform for the service fulfillment of humankind and its subsystems provide a variety of required functionality. However, a habitat service system is unlike a space station in that it integrates into a larger ecological environment, whereas a space station is designed to isolate its occupants for their protection. A city ought to connect and facilitate the adaptation of a life form to its environment. Also, it may provide protection, but if it isolates its users/occupants from the larger habitat, then its users are likely to become disoriented from their highest potential trajectory in life. In reality, a service system (a city) must allow for the thoughtful flow energies with the larger ecological habitat if it is to flourish.

A city is where many people gather and live. A city is more than just an architectural expression -- it involves more service functions than just providing architecture for a population.

As a complex system, a city can express the following properties:

1. A city is a group of people and a number of permanent structures within a geographic area. In the market-State, said organization exists to facilitate social control and the trade of goods and services among residents and with the outside world. In community, said organization exists to facilitate so organized to facilitate human fulfillment.
2. A city is a center of, and for, human activity.
3. A city is a spatial pattern of human activities and their materializations at a certain point in time (note that this is often the definition for the term 'urban').
4. A city is an environment (space) configured through flows (exchanges, networks) of communication and the transport of matter and energy.
5. A city is an environment built for a social population.
6. A city is a network of people, information, and material flows designed to fulfill the requirements of a population. A city is a complex interconnection of people, information, and material flows. Therein, a city is a material system designed through the information system of a social population.
7. A 'city' is an information and spatial service system.
8. A city is an information and material processing system/platform that has been engineered for a social population.
9. A city is a socio-technically built environment that has been engineered to socio-technical specification standards. A city as a built information medium.
10. A city is the materialization of a population's socio-economic [information] system.
11. A city contains subsystems that provide structural and functional meaning, interconnected and enabled by networks of people, information, and material flow, as well as characterized by social, decisional, material, and lifestyle aspects.
12. A city is a habitat service system to fulfill human requirements.
13. A city is a multi-physic object, characterized by a dynamic interrelationship of energy, materials, information and human activities and behavior (Stepandic, 2019). In this sense, a city could be considered a "living" object of human, informational, and material interrelationship.
14. A city is an evolving, living system in complex interaction with its population, its artificially materialized environment and its natural physical environment.
15. A city is an environmentally controlled area.
16. A city is a living complex of geometrical and topological objects, limited in its material (artificial and natural) environment.
17. A city is sustained (operated) and lived in by its population, constrained by decisioning and physical laws.
18. Cities are hubs of people, supported by infrastructure. Cities are where people come together to experience the benefits of being together in close proximity - to access to services and opportunities.
19. A city is materially encoded intelligence (or, lack thereof).
20. A city is a place where people live and work and play together. A city is a live-work (or, live-work-play) environment.
21. A city is an environment that optimizes (or, should optimize) for the quality of life of the beings in that environment.

A city is a place where people live and work together under the same infrastructure:

1. City infrastructures are an enabler of collective living and working.
2. Infrastructures affect the "life" and behavior of a city.
3. Infrastructures are affected by the "life" and behaviors of a city.

A city is a place where people live within the same [type of] society:

1. A city is [the result of] a social system.
2. A city is [the result of] a decision system.
3. A city is [the result of] a material system.
4. A city is [the result of] a lifestyle system.

A city is a system with:

1. Feedback loops (inside and across sub-systems)
2. Complexity (interrelatedness)
3. Path dependency
    A. Socio-systems
    B. Technical-systems

> **INSIGHT:** *In a city, people are likely to connect only if a city's human-scale geometry creates shared spaces with the right complexity.*

In the controlled habitat of the Community (i.e., the Habitat Service System, the "city"), everything is analyzed and broken down for functional use by its users.

1.1 Types of cities

> *A.k.a., Cities in community and other types of society.*

In any society, cities are the product of that societies societal information set. In other words, cities arise and are reconfigured based upon a given society's information system, whether that system is made explicit or not. Different types of societies create different types of material environments, and therein, different types of cities:

1. Community-cities (a.k.a., integrated city systems, total city systems, etc.) - cities developed in community.
2. Market-State cities (a.k.a., market-city system, State-city system, smart city system, etc.) - cities developed for the market-State.

Fundamentally, specific organizations of cities play a key role in the systemic transition towards a more sustainable way of living.

1.1.1 Community-type cities

A.k.a., Community-cities, cities in community, community-based cities, community-type cities, integrated city systems, total city systems.

The term, 'community-city', is referential of the 'city' emerging as the material expression of a community-type society. Therein, 'community' is the term giving to the living system (i.e., society) as a whole, and the 'city' is its material expression. A community-city is a material ecosystem designed to facilitate the experience of a greater sense of connection and integration within each individual. Community-based cities are hubs for the sharing of access. Cities in community are complex socio-technical environments where access and services are available for free. Most cities in community are largely autonomous; however, some populations have chosen to live in low technologically developed cities where there is little application of autonomous systems. These low-tech city systems are often significantly reduced in population size and carry capacity compared to their high-tech alternatives. Effectively, community-type cities are integrated socio-technical service systems designed to fulfill the needs, wants and preferences of a population of human beings in a regenerative and emergent manner.

A community-city is an integrated (total) socio-technological service system for providing material need fulfillment to a network of humans in a sustainable manner at pre-planned population scales. Therein, a city is the materialized reflection of socio-decisioning and lifestyle design.

1.1.2 Market-State cities

A.k.a., Industrial cities, modern cities, early 21st century cities.

All known cities to date are market-State cities. A State-city or city-State refers to a population center for social interaction within a territorial authority, the "jurisdiction" (i.e., a government body). State-based cities are governmental controlled environment (i.e., population-controlled environments). The population of a city-State is often called its "citizenry" -- the population are "citizens" of a particular jurisdiction. Here, a city is a center for national/local government. The state controls (or, restrains) the behavior of citizens in a city through laws and law enforcement (i.e., the monopolization of force/violence).

A market-city or city-market refers to a city designed to accommodate the market. In the market, a city is a center for trade and financial investment. Market-based cities are designed around ownership and businesses. Individuals in a market-city are generally referred to as owners. A market-State city is necessarily divided up into plots of ownership, often, starting with that which is owned by the local governing authority. In fact, nearly all cities in early 21st century society are entirely owned by their local governing authority, which rents the land to secondary owners by means of taxation. Hence, market-cities are actually city governmental markets. Thus, a city is a conglomeration of people and buildings clustered together to serve as a center of politics, culture, and economics. Therein, a city is an environment in which people compete for resources.

TERMINOLOGY: '*Urbanization' is the growth and diffusion of city landscapes and urban lifestyles.*

Cities within the market-State are developed around entirely different purposes than those developed for/in community. Early 21st century cities are a central hubs for competition, and the vast majority of them are designed primarily for automobile access. Modern cities are full of passive commercial attractions, and capital cities are full of embassies.

In the market-State, market demand is closely related to the size of any given economy, population, and income level of a city. Therein, different aspects of the market and State determine the spatial distribution, size, direction, and model of the production and circulation of goods and services within and between cities. (Ni, 2007)

Market-State cities in the early 21st century are generally designed along five business lines (*Systems of Cities*, 2009):

1. City management, governance, and finance.
2. Economic growth.
3. City planning, land, and housing.
4. Urban environment and climate change.
5. Handling urban poverty.

Note: These business items set out the objectives and benchmarks for financing and policy advice.

The majority of data available on land and resource requirements to support a market-State city in the early 21st century is mostly irrelevant to the design of a city as a habitat service system in community. For example, the amount of food volume necessary to support the population is different since a community's service system accounts for nutritional density, which is something modern socio-economic service entities do not account for in their data. Further, there is no financial system in a community-city, which makes data tainted by financial bias somewhat useless.

NOTE: *Market-State cities manage the poor instead of creating environments that don't produce poverty.*

In the early 21st century, some market-State cities are centuries old, having been built up and outwards for thousands of years. The lives of the current inhabitants of these cities are significantly shaped by centuries old structures and layouts that are creations of those with knowingly outdated understandings and value sets. In other words, the beliefs and values of those long dead are still affecting the day-to-day lives, behaviors and lifestyles, of city residents in the early 21st century.

Living systems survive, connect with their environment, and reproduce themselves. The biophysical facts of life then set up the conditions for individual survival and species survival. The city is just a natural and inevitable outcome of human behaviors that have resulted from human evolution. But, it has also become a life condition itself that directly impacts well-being. Cities in the early 21st century (and their suburbs) represent the structural encoding of a value orientation away from one of a resilient living system. To flourish, humanity must redesign its city habitats to more greatly encode and restore a life-fulfilling value set.

It would be far easier and would require less energy to build new, efficient cities than to attempt to update and solve the problems of the old ones. (Circular cities, 2020) The question then arises, what would be done with old cities in a global community-type society? Most of the old cities would be leveled and mined for their resources. They are too inefficient to maintain. Some of the cities would be set aside as museum cities. (FAQ, 2020)

INSIGHT: *In making the city, we make the world more after our "hearts desire", but in making that city we also make our future selves.*

1.1.3 Smart cities

A.k.a., Smart urbanism, electronic government, electronic infrastructure, urban operating system.

Smart cities are, generally, more technologically advanced cities in the market-State. A smart city is the conception of a city that uses technology to enhance governance, planning, management, and livability of a city by gathering and processing real-world, real-time data. Therein, city residents and visitors are claimed to live more easily (i.e., more conveniently) due to the integration of these "smart" technologies (i.e., sensors, computing, and automation systems). In terms of city management and service coordination, "smartness" also refers to applying information technologies to different stages of planning, designing, building, and operating cities. (Ronkko, 2018) There can be found more than 36 distinct definitions of the "smart city" concept in a current scientific literature. (Stepanek, 2019) A generalized definition of a "smart city" is a city that uses "electronic Internet of Things (IoT) sensors to collect data and then use insights gained from that data to manage assets, resources and services efficiently". (*Smart city*, 2020) The first attempts to define the concept were focused on the connectivity and features provided by information technology for managing various city functions (i.e., electronic government; e.g., smart meters). More recently, the usage of the term has widened in scope to include the outcome of a "smart city", such as sustainability, quality of life, and services to the citizens. (Ramaprasad, 2017) Of course, these outcomes are generally defined within the context of the market-State.

INSIGHT: *A city could be viewed as a living organism that needs to fulfill specific goals for the city to preserve its existence. Note that this is of course a reification of the city, which could lead to misunderstanding. A city is not, in fact, a living thing; it is the humans (and other organisms) inside the city that are living and that which have need. In actuality, the city exists to fulfill a purpose beyond itself, for humanity.*

Ramaprasad et al., (2017) have proposed a Smart City ontology that attempts to connect early 21st century definitions and unify the concept of a "smart city". Ramaprasad et al. (2017) and Stapanek et al. (2019) consider the ontology a better way to organize smart city concepts than a single definition. This ontology defines the "smart city" concept as a function of two main parameters: smart and city. For each parameter, there is a function that explains the dimensions of the parameter. The concept Smart contains Structure, Function, Focus, and Semiotics. The City consists of Stakeholders and Outcomes. Each dimension from "smart" and "city" is sub-defined as a set of components (or classes).

For the "smart" dimension:

1. Structure includes: Architecture, Infrastructure, Systems, Services, Policies, Processes, and Personnel elements.
2. Function includes: Sense, Monitor, Process, Translate and Communicate.
3. Focus includes: Cultural, Economic, Demographic, Environmental, Political, Social, Technological and Infrastructural elements.
4. Semiotics includes: Data, Information, and Knowledge.

For the "city" dimension:

1. Stakeholders is constructed by: Citizens, Professionals, Communities, Institutions, Business, and Governments.
2. Outcomes include: Sustainability, Quality of Life, Equity, Livability, and Resilience.

The following glossary (Ramaprasad et al., 2017) is necessary to understand the whole definition:

1. Smart: Capable of sensing and responding through semiotics.
   A. Structure: The structure required to manage the semiotics.
      1. Architecture: The architecture to manage the semiotics.
      2. Infrastructure: The physical and virtual infrastructure to manage the semiotics.
      3. Systems: The computer, social, and paper based systems to manage semiotics.
      4. Services: The computer, social, and paper based services to manage the semiotics.
      5. Policies: The policies to manage the semiotics.
      6. Processes: The processes to manage the semiotics.
      7. People: The people responsible for managing the semiotics.
   B. Function: The functions required to manage the semiotics
      1. Sense: To sense the semiotic elements.
      2. Monitor: To monitor the semiotic elements.
      3. Process: To process the semiotic elements.
      4. Translate: To translate the semiotics into action/control.
      5. Communicate: To communicate the semiotic elements.
   C. Focus: The focus of intelligent sense and response (i.e., "smartness").
      1. Social: Social dynamics of the city.
      2. Economic: Economic dynamics of the city.
      3. Environmental: Environmental dynamics of the city.
      4. Technological: Technological dynamics of the city.
      5. Infrastructure: Infrastructure dynamics of the city.
   D. Semiotics: The iterative process of generating and applying intelligence.
      1. Data: The symbolic representation of sensations and measurements.
      2. Information: The relationship among data elements.
      3. Knowledge: The meaning of the relationships among the data elements.
2. City: A city capable of intelligent sense and response.
   A. Stakeholders: Those affecting and affected by the city.
      1. Citizens: Citizens of the city.
      2. Professionals: The professionals of the city.
      3. Communities: The communities of the city.
      4. Business: The businesses of the city.
      5. Governments: Federal, State, and Local governments.
   B. Outcomes: The desired outcomes of a city.
      1. Sustainability: Sustainability of the city.
      2. Quality of life: Quality of life of the stakeholders.
      3. Livability: The livability of the city.
      4. Resilience: The ability of the city to recover.

Herein, the "smartness" of the environment affects the "city" in which people live. The expression between classes of the dimensions "smart" and "city" is:

> **Smart** *(Structure [+] Function [+] Focus [+] Semiotics) [by/from/to]* **City** *(Stakeholders [+] Outcomes)*

Therein, a "smart city" is compound function with two parts/dimensions:

> *Smart City = f (Smart + City)*

The "city" is a function of stakeholders and outcomes.

> *City = f (Stakeholders + Outcomes)*

The "smartness" of a city is a function of structure, function, focus (direction), and semiotics (information processes):

> *Smart = f (Structure + Function + Focus + Semiotics)*

Ramaprasad et al., (2017) define 'semiotics' as, the iterative process of generating and applying intelligence. Semiotics forms the core of the "smart" dimension, such that all other classes of this dimension refer to it. The direction of "smartness" is the "outcomes", which are of interest to the "stakeholders". The direction of "smartness" depends on the "structure" and "functions" of the systems for semiotics. The iterative "semiotics" process, involves data that are converted into information, information to knowledge, and the knowledge is then translated into smart actions. The "focus" of "semiotics" are the relevant possible sub-conceptions of the society and city. The semiotics of each focus will affect the corresponding smartness of the city, its stakeholders, and the corresponding outcomes. The "structure" and "functions" of a city's semiotics (i.e., data, information, knowledge) information system (or, management/coordination system) will determine its "smartness". Together, the four left dimension of "smart" are concatenated to form the "smartness" of a city. Taken together, there are 7*5*8*3*6*5 = 25,200 potential components of a Smart City encapsulated in the definition/ontology. A truly "smart city" is one that has realized a significant portion of these potential components.

Four concatenations are listed below as an example of the 25,200 possibilities:

- Architecture to sense economic information by/from citizens for quality-of-life.
- Systems to process environmental data for livability.
- Policies to communicate technological knowledge [by professionals] for resilience.
- Processes to translate political information to citizens for sustainability.

> **NOTE:** *This ontology and the following functions are bounded by the conditions and conceptions of a market-State society, and are not entirely representative of a "smart city" in a community-type society.*

Stapanek et al., (2019) note three additional papers that facilitate further explanation of the "smart city" ontology as a function. Babar and Arif (2017) propose a functional ontology with several layers. The first layer is an architecture for planning and decisioning. The second is data acquisition and aggregation, mainly using IoT components, and the last uses pre-processed data for taking decisions and communicating events to citizens:

f (f (architecture
+ (monitor, process, translate, communicate)
+ urban + data)
+ f (citizens + quality-of-life))

Uribe-Perez and Pous (2017) propose a communication architecture inspired by a human nervous system. The architecture is composed of:

1. A sensing layer containing a sensor network.
2. An access layer with "smart" gateways to process a low-level information and act consequently.
3. A data layer with sufficient (e.g., 3) types of databases to store data.
4. A platform layer to supervise and manage the city.
5. An application layer to provide services.

The ontological function is:

(f (architecture
+ (sense, monitor, translate, communicate)
+ urban
+ (data, in formation))
+ f (stakeholders + resilience))

Chen et al., (2016) propose an automotive sensing platform used in the city to obtain data from different parts of the city by cars equipped with sensors. The ontological function is:

f (f (platform
+ (monitor, process, communicate)
+ data))

1.1.3.1 A smart city ontology under community conditions

A glossary for a similar ontology to Ramaprasad et al., (2017), but applicable for community conditions would resemble (differences are underlined):

1. Smart: Capable of sensing and responding through semiotics.
   - A. Structure: The structure required to <u>coordinate</u> the semiotics.
     1. <u>Information technology: The software and hardware to coordinate</u> the semiotics.
     2. <u>Projects</u> (services): The <u>projects</u> (services) to <u>coordinate</u> the semiotics.
     3. <u>Teams</u>: The <u>teams</u> responsible for <u>coordinating</u> the semiotics.
     4. Processes: The processes to <u>coordinate</u> the semiotics.
     5. <u>Procedures</u>: The <u>procedures</u> to <u>coordinate</u> the semiotics.
   - B. Function: The functions required to coordinate the semiotics
     1. Sense: To sense the semiotic elements.
     2. Monitor: To monitor the semiotic elements.
     3. Process: To process the semiotic elements.
     4. Translate: To translate the semiotics into action/control.
     5. Communicate: To communicate the semiotic elements.
   - C. Focus: The focus of intelligent sense and response (i.e., "smartness").
     1. <u>Resources</u>: Resource dynamics of the city.
     2. <u>Access</u>: Access dynamics of the city.
     3. <u>Social</u>: Social dynamics of the society.
     4. <u>Decision</u>: Decision dynamics of the society.
     5. <u>Lifestyle</u>: Lifestyle dynamics of the society.
     6. <u>Life support</u>: Human life dynamics (or, services) of the city.
     7. <u>Technological support</u>: Technological dynamics (or, services) of the city.
     8. <u>Exploration support</u>: Human exploration dynamics (or, services) of the city.
   - D. Semiotics: The iterative process of generating and applying intelligence.
     1. Data: The symbolic representation of sensations and measurements.
     2. Information: The relationship among data

elements.
3. Knowledge: The meaning of the relationships among the data elements.
2. City: A city capable of intelligent sense and response.
   A. Stakeholders: Those affecting and affected by the city.
      1. Users: Users of the city.
      2. Teams: The developers and operators of the city.
   B. Outcomes: The desired outcomes of a city.
      1. Values: Values of the society.
      2. Fulfillment: Fulfillment of the stakeholders.
      3. Flourishing: Flourishing of the stakeholders.
      4. Quality of life (well-being): Quality of life of the stakeholders.
      5. Flow: Flow of the stakeholders.

Four concatenations are listed below as an example of the 6,000 possibilities:

- Information technology to sense life support information by/from users for quality-of-life. Sensors and surveys to sense the quality-of-life of the users of the city and make the data available to users.
- Projects to process resource data for fulfillment. Projects to determine water pollution levels and warn users and teams when they exceed acceptable thresholds.
- Procedures to communicate knowledge for flourishing. Procedures (e.g., notifications) to share knowledge about technological changes to the city with various teams.
- Processes to translate decision information to teams for values encoding. Processes (e.g., optimization algorithms) to translate the social values of the users into decisions that may affect the sustainability of the city.

Using the same expression as Ramaprasad et al., (2017) between classes of the dimensions "smart" and "city", there are 5*5*8*3*2*5 = 6,000 potential components of a "smart city" encapsulated in this definition/ontology. Note that this figure will be off due to the outcome measures not being completely elaborated. For instance, the values are not delineated herein. The market-State is a significantly more complex and convoluted environment than a community-type society, which is why there is such a significant difference between Ramaprasad et al., combinatorial figure of 25,200 components and the 6,750 components of community.

1.1.3.2 Commercial smart city software solutions

There are an increasing number of software and hardware solutions designed to facilitate smart city development and operations, these include but are not limited to:

- IBM: *Smarter City*
  - *Intelligent Operations Centre for Smarter Cities*
- Urbotica: *City Operating System*
- Microsoft: *CityNext*
- Rio de Janeiro: *Centro de Operações*
- Barcelona: *City OS*

2 City design in community

INSIGHT: *A community-city is a whole-expression of our humanity.*

Generally speaking, there are many factors to account for in city design. Sky, atmosphere, and orography generate variable meteorological conditions over a city (e.g., could covering shade, solar, wind, rain, etc.). Buildings and other standing objects/structures induce field dynamics in the environment, including but not limited to: masks, reflections, absorptions, re-emission, rainwater runoff, etc. Human activities produce issues, including but not limited to: heat, noise, waste, pollution, etc. And, human needs (and wants) produce requirements, including but not limited to: life support, technology support, and exploratory support.

Community cities employ the scientific method, prioritizes efficiency throughout appropriate design, have a cooperative versus competitive social structure, are high tech and highly automated, and are the result of a systems approach in managing its complexity. Such cities are a world benefiting platform for the sustainable advancement of humankind. Community cities are circular (generally), fully sustainable, appropriately functional, and access-oriented environments, built for those who are actively engaged in living their life to the fullest. In the 21st century, physics and computing are necessarily part of the whole infrastructure of densely populated (and sometimes even, low-density populated) habitat service systems, necessarily so.

Cities in community are entirely open source. The result of this openly sourced way of living is that there is the maximization of everyone's potential quality-of-life, and neither hoarding nor fighting over ownership. Community-based cities are operationalized to be continuously up-to-date with humanity's knowledge about how to live more optimally, while drawing upon humanity's inherent and individual strengths. Therein, individuals experience a space where knowledge is applied for the well-being and benefit of all. A lot of the work in these cities has been automated to free up time for individuals to pursue their passions and greater interests. Herein, automation and technology is intelligently integrated into an overall holistic socio-economic design, which primarily functions to optimize the quality-of-life of every individual.

It is possible to have a network of sustainable city systems where humanity has intelligently organized free access to that which is needed so that everyone may thrive; in contrast to an unstable living arrangement where individuals exchange artificial intangibles that everyone is coerced into acquiring and using for [at least] their mere survival, generating socio-economic inequality and the vast number of public health issues that are causal consequences therefrom.

Cities in community provide free access to all goods as services, as in nature, so that individuals don't become constrained (limited) by the abstract intangible known as "money", and hence, disconnected in their ability to accurately sense and appropriately respond to environmental signals. If people have access to the necessities of life they don't "steal", and "crime" (as it is known in early 21st century society) is rendered almost non-existent. The notion that things are "free" in community is something of a misnomer, because there is no money in community. In fact, community can only emerges in a world where everything has been coordinated to be accessible without the need for exchange (i.e., without 'trade').

It is possible to design cities where it is more enjoyable to walk or bike, than to drive, thanks to the intelligent and integrated layout of the physical environment. Among community, individuals walk through the majority of their beautifully planned daily life-space, wherein, they experience a living socio-economic system structured to coordinate decisions, and the flow of resources, for their fulfillment. Therein, individuals experience intentional design that supports a high quality-of-life for themselves and all others; it's an environment where technology and economy serve humanity and the ecology, not the other way around. It is an environment where human creations provide everyone with an abundance of access to life enriching opportunities, maintaining a support structure for living better lives - lives in alignment with the development of individuals' true potential. It is an environment that draws out the best in each individual; pulling out from them the energy of happiness, well-being, and deeply felt love and connection for one another and the universe. These cities are designed provides vast opportunities for outward exploration, as well as the space for humanity to go inward and experience states of universal being. Here, decisions and actions entangle one another in a direction commensurate to humanity's highest potential.

Community-based cities are designed so that there exists the values of efficiency and effectiveness in the fulfillment of human needs, wants, and preferences. Food, energy, transport, and production, for example, have efficiency as a core priority in their designs, which is a necessity for the sustainability of complex socio-technical systems. Material and service constructions are designed to meet human requirements in the best possible manner with the least usage of resources and effort. Conversely, in a monetary system, such designs are generally too expensive. The costs of trying to create a sustainable and efficient city inside a for-profit paradigm are simply too high, which is one of the many reasons there is not a single city optimized for human well-being in early 21st century society. There is very little that is sustainable in how cities in early 21st century society are designed, or the monetary and authority driven social values that have been adopted by their constituents.

Community-based cities are, in general, designed such that food cultivation and natural beauty are integrated into all appropriate and desirable spaces. As a city, community is a place in which all of the tasks (i.e., "jobs") are actually worth doing. Because of the encoding of the value of transparency, everyone in the city knows what needs to be done, and can contribute to the system's continuation and evolution in a coordinated and planned manner.

In community cities, individual's time is their own ad is not structured by coercive structures and authority figures. Here, opportunities for access, self-growth, and contribution are ever present. Individuals' contributions directly benefit everyone, as opposed to working for the direct benefit of someone else or some specifically competitive organization. All work (as effort applied toward the community's continuation and evolution) is relevant, and everyone "owns" their own time.

Due to the intelligently planned design of these cities there are no "prime locations" (as there are in market-State cities); instead, everyone has access to a prime location. Often, it is possible to walk around the living environment and freely pick a variety of flavorful and nutritionally dense foods without worrying about pollution and other toxic residues. These cities feel

> **QUESTION:** *How would it feel to live in a place constructed to express conditions of interest in your well-being as well as facilitate empathic concern for the well-being of others? It may feel like a city that has been designed openly, by all of us, and for all of our well-being.*

Neither the market nor the State has been encoded in a community-type city, and therefore, there is no revenue, no taxation, and no materialization of an environment focused around competition, ownership, and authority. Living in the early 21st century involves (and, for most people it requires) property ownership, and there are taxes and other fees that go along with that ownership. In order to have access, that sort of socio-economic arrangement necessitates either having a job to pay for things, or becoming a ward of someone else who pays for those things. Of course, cities in early 21st century society consequently look and feel very different than they do in community. In the market-State, cities are products and the people within them have little choice but to work for a boss, go on the dole, or starve. Oddly, there is a segment of this population that believes they have something they call "freedom of choice". What they actually have is the illusion of choice, because the options from which they can "choose" have already been decided upon by the structure of the system itself and the "decision makers" higher up in the socio-economic hierarchy or in the distant past; and, these pre-selected options are inescapable if survival is desired.

In community, there is no commerce, no economic trade or exchange of goods, no socio-economic classes or hierarchy, no politics, no bureaucracy, no police, no prisons, no trash, no poverty, no homelessness, and no congestion. When arriving in community from early 21st century society, there is a sense of relief that these things that have held humanity's potential down for so long are no longer present. And still, community creates a city where children and adults alike play outside safely at any hour. Therefore, community is an environment that notably lacks any and all advertising and marketing, in both the physical and digital space. There is no surveillance or misinformation, which are present almost everywhere in cities in the market-State. And yet, the city looks beautifully up kept, it is intelligently laid out, and as individuals move about they don't have to worry about walking on grass or other surfaces that have been sprayed with various killing substances, such as pesticides and herbicides. In community-based cities, no one has to wash industrial pollutants off of their food, or personally filter their water to remove pharmaceuticals, commercial by-products such as sodium fluoride, and other industrial contaminants.

> **INSIGHT:** *Among community, we have a saying, "Systems are what they produce, not what we wish them to produce."*

Individuals in early 21st century society have become habituated to the constant stimulus of commerce and advertising, which wears down (i.e., wears away) their sensitivities to their own needs and their environment. Cities in community are notably void of trash and other pollution. Over time, such pollution causes individuals to turn off from environmental stimuli. The continuously hostile environment of market-State cities causes people to not want to feel their sensory inputs. And, that is the weirdest thing to imagine, that you have to stop perceiving your environment to keep yourself sane. Of course, the light pollution in early 21st century society affects people's sleep, their circadian rhythms, and it prevents them from seeing the stars, which would otherwise provide them with a nightly connection to the larger universe.

In community, the living environment itself almost feels like a single self-regulating and self-healing organism. Community is similar (in this respect) to the human body, which wants to feel well and heal, but needs the correct inputs as well as minimal interference from that which is malignant. Community is a type of society run so efficiently and with organized care that it feels like it takes care of itself. All of those things that are essential for individuals to survive and thrive are integrated and engineered into a unified habitat service system, a city. A city that mirrors the operation of our natural world, which is itself a collection of integrated systems.

> **QUESTION:** *What would society look like if it inherited those properties of the universe that we see as it's incredible harmony and mathematics and self-organization? And, what would it look like if our intention for its creation was to be of benefit to the individual, of benefit to the social, and of benefit to the planet (and even, possibly, the very universe itself)?*

2.1 The integrated city system

A.k.a., Total city system, intelligent city system, *unified city system, cooperative city system.*

All city systems in community are integrated city systems. An integrated city system is, in part, in one in which the informational and physical systems of the city are accounted for together in the design and operation of the city. Additionally, integrated city systems account for the total system state of city in relation to its inhabitants and their requirements of the city. Information unification (i.e., looking at society and its cities as an information system first) allows for true cooperation among individual humans and the organization of an integrated living environment.

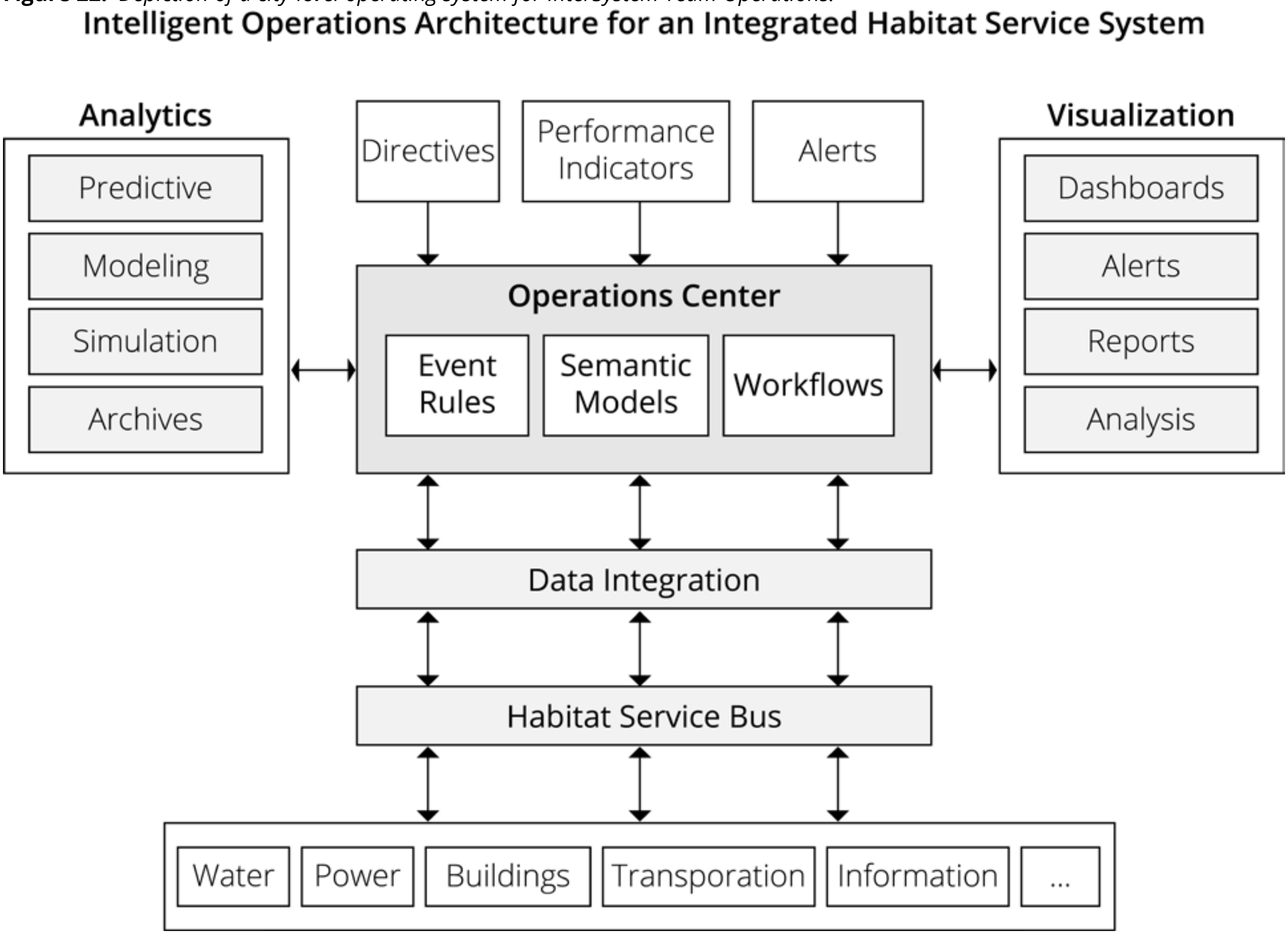
In order to create a life radius that fulfills humanity's real world needs and requirements, cities in community are designed in an integrated manner, and hence, they are often referred to as "integrated city systems" or "total city systems". An integrated city system (a.k.a. total city system) is a city in which every element operates together efficiently as a whole system. In other words, all aspects of the construction and functioning of a community-type city are well integrated. Instead of leaving city functions under the control of isolated organizations, individuals and obscured programs, cities in community integrate their control. All functional aspects of these cities, from food cultivation to sewage and energy production are processed together as one system (i.e., they are 'integrated'). Integrated city system are strategically planned and cooperatively operated socio-technical environments. In order to accomplish their functions, integrated city systems are data collection and product materialization platforms.

City systems in community are integrated living environments. Significantly, said city systems are [sustainably] integrated into the planetary biosphere/ecology by means of a planned and bounded service area known as a habitat service system. Therein, these cities are integrated into the form of a human habitat through intelligent socio-decisioning and thoughtful material and lifestyle design. Community cities are based on individuals who play an active part in their design and operation.

An integrated city system is one in which:

1. The elements of the city are interconnected (informationally and spatially).
2. Access to all parts of the city exists through continuity of travel by various modes of transport.
3. The city layout exists by reason of <u>function</u>, <u>demand</u>, and <u>optimization</u> (i.e., function,

Figure 22. *Depiction of a city-level operating system for InterSystem Team Operations.*



effectiveness of fulfillment, and efficiency of fulfillment).

In community, ideas and designs are well thought-out and coherently integrated into a unified information system [model] before being encoded into decisioning and constructed into the environment, whereupon they are tested to ensure desired alignment. A total city system approach requires systematic design and overall planning to attain a high standard of living for all the occupants.

NOTE: *A total city system is a city that accounts for the total (whole) environment.*

It important to address an issue here: the notion that intelligent core-systems planning, implies mass uniformity, is not accurate. Cities in community would be uniform only to the degree that they would require far less materials, save time and energy, and be flexible enough to allow for innovative changes (through modularity), while preserving the local ecology. Cities in community are planned so that they are capable of fulfilling the needs, wants and preferences of all community inhabitants. Through planning and testing we are able to produce a pleasant and desirable living space that removes urban sprawl and can effectively account for social, economic, and ecological problems. The integration of function is necessary for the optimization of our fulfillment, as well as an accountable solution-orientation to any problems that may arise.

Herein, information processing and automation systems are combined with sensors and human effort (where necessary and/or desired) to optimize the operating efficiency of the city. The use of up-to-date technological methods, including electronic feedback, digital information processing, and automation, is applied to the entire city system. The use of automation ensures that what we intend to happen, actually does happen, every time we want it to happen. Through the application of computing we are able to process trillions of bits of information per second, which is useful (though not absolutely essential) for the facilitation of complex multi-variate decisioning, and hence, the coordinated operation of these cities. Intelligent coordination keeps a city's services operating at peak efficiency and uptime, maintaining our materially desired fulfillment, and creating an optimized economy that avoids overruns and shortages. For example, the irrigation and fertilization of a primary food cultivation belt (within one of these cities) is programmatically controlled through an automated irrigation system involving environmental sensors, integrated circuitry, and various mechanical technologies. Hence, the emergence of a service system that frees humans from unnecessary labor, makes the most efficient use of resources (water in particular), while ensuring a sustained healthy landscape. Waste management, energy generation, and other services are managed by these "smart" (i.e., "cybernetic") methods. This integrated control is openly programmed by us, for us (as a community), and applied throughout these city systems for social and ecological concern.

Additionally, an integrated city system is also defined by the consolidation of as many functions as possible (or desired) into the least amount of material area. For example, most of the outer surfaces of buildings convert solar energy into electricity, and the surfaces are themselves fitted with automated cleansing systems.

Integration, not only within a city itself, but between cities provides innumerable benefits, including but not limited to:

1. Increased ability to identify problems.
2. Increased ability to aggregate information and identify useful/applicable information.
3. More informed responses.
4. One platform provides better coordination.
5. Better communication and cooperation.
6. Increased safety.

The total societal system may be delineated as follows:

1. One solar and planetary system.
2. One unified societal system design [specification standard].
3. Four societal information sub-systems (social, decision, material, lifestyle).
4. One global habitat service system (network of city systems, the economic global access system).
5. The local habitat service systems (individual, integrated city systems).

2.1.1 The cybernetic city

A.k.a., The cybernated city, the computationally integrated city, the diagrammatic city, the smart city, the computational city, the intelligent city, the automated city, the computed city, the city operating system, the urban operating system, the city information system, the city central processing system, cyber-physical-social systems (CPSS).

Cybernetics is an interdisciplinary science for exploring digital, mechanical, or biological regulatory systems. (Wiener, 1948) Classical cybernetics has evolved, since its instantiation in the 1940s into second (or, third) order cybernetics-the cybernetics of observing (includes the observer, rather than only being observed) systems, which also concerns the principles of learning and communication. (Ross, 1957; Glanville, 2007) In line with the original meaning of the word, "to steer, navigate, or control", cybernetics can be applied to the design and operation of any complex system, including cities. (Ronnko, 2018)

NOTE: *The central element(s) in cybernetics is control, which implies feedback, decisioning, and communication, which all involve the* *transmission of information.*

At the core of a cybernetic city (a.k.a., smart city) is a software control (i.e., cybernetic) center in which planning and operations occur. Since the science of cybernetics focuses on the information and communication involved in the process of feedback and decisioning, a cybernetic city is one in which the latest information and technology is utilized to maximize the fulfillment of the inhabitants. (Lasker, 1981) At the core of cybernetic city operations are clear, real-time situational information for monitoring, analyzing, understanding, planning, and operating smart cities.

NOTE: *The idea of a cybernetic city and the emerging conception/ontology of a smart city are highly related, except that the cybernetic view is more systems- and community-based, whereas the notion of a smart city is more based in the market-State ideology.*

A cybernetic city is a cyber-physical-social system. Common cyber-related terms to understand this complex relationship include, but are not limited to:

- **Cyber-social systems (CSS)** - social systems with embedded digital structures and devices to facilitate human scale endeavours. Cyber-social systems are a collection of technologies for coordinating and controlling interconnected social and computational capabilities. CSS is the merger of cyber (electric/electronic) systems with social structures.
- **Cyber-physical system (CPS)** - is a system featuring a combination of computational and physical elements, all of which are capable of interacting, reflecting and influencing each other. Cyber-physical systems are a collection of technologies for coordinating and controlling interconnected physical and computational capabilities. CPS is the merger of cyber (electric/electronic) systems with physical things. (Trappey et al., 2016) For example, mechatronic systems, which combine the disciplines of mechanical, control and electrical engineering. CPS systems include automated systems that sense and control physical phenomena through sensors, processors, and actuators.
  - **Human-in-the-loop (HiTL) CPS** - CPS systems that involve control loops with human goal-oriented interaction.
- **Cyber-physical-social systems (CPSS)** - the integration of cyber space, physical space, and social space.

Fundamentally, cybernetics is the science of self-regulating systems, which (1) exist in living matter and its relationship to its environment, (2) as the interaction among living things, (3) in machines, and (4) in the interaction between living things and machines. In the context of cybernetics, self-regulation includes processes that maintain organisms or organizations as viable entities and that enable machines to perform selection and control operations. (Lasker, 1981) A city system that is systematically involved in the production, organization, distribution, and use of knowledge and information, which constitutes a self-regulating city system.

Amstutz (1968: 21) states that a city could be made more response to its populations needs via a threefold strategy:

1. Structuring the environment into categories and subcategories. For example, identifying the core services of the habitat (e.g., life, technology, and exploratory).
2. Developing clear objectives and criteria for evaluation. For example, what is flourishing, fulfillment, and quality of life, and how are they measured.
3. Using computers to 'synthesize and maintain a representation of the total environment'.

Amstutz's approach rests on the delegation of control ("authority") to computer systems. If city functions were pre-programmed, then city planners and operators would be able to approach city problems with '"increased effectiveness due to the availability of more meaningful data and an increased (model based) understanding of [the] environment" (Amstutz, 1968: 21).

INSIGHT: *Intelligent systems evolve through feedback phenomena. Feedback is an essential action in the generation of a sustainable city environment, for both the efficient use of resources and the integration of effective functionality.*

Computer science, systems science, and simulation are early sources of inspiration for viewing the city as an operating platform for humanity. Since the 1950s and Norbert Wiener's laying out the principles of cybernetics, the city has increasingly come to be viewed as a communications system. (Meier, 1962; Webber, 1964; see also Light, 2003) The city is a space of data flows and environmental modelling is traceable to the digital computation work of Forrester (1961; 1969). Forrester thought of cities from a scientific perspective (as in, the 'science of cities'; Batty, 2013; see Townsend, 2015 for a critique), and saw the city as a complex (yet arguably linear) system of interacting parts experiencing growth, equilibrium and stagnation; a system easily modelled through calculated flows and an account of conditions in the surrounding environment. Batty et al., (2011) state that, "One of the key differences between theories of cities developed a half century or more ago and the emerging science of cities and societies in the early 21st century revolves around the idea that the focus should no longer be on location, but on interactions and connections, on networks and the concomitant processes that define flows between places and spaces." The understanding that computer applications, system dynamics and digital modelling are mechanisms to solve societal, and particularly, city problems was espoused by a generation of planners and technologists, one of the most notable being Jacque Fresco who envisioned architectural structures (and even, whole city systems) optimized for and by computer aided environments. (Fresco, 2007)

An cybernetic city system establishes a diagrammatic form of relationship with the city. Diagrammatic modeling and simulation occurs for information structures and dynamics as well as spatial structures and dynamics. Informational diagrammatic control involves the visualization of information to easily identify functions and simplify decision selection. In effect, a unified city operating system establishes a diagrammatic form of relationship with the city. (Marvin, 2017: 92) Fundamentally, cities can be visualized, diagrammed, and all aspects can be simulated. Therein, coordination and control of the [cybernetic] city is given over to computational logic-- involving the coordination of information and material flows through information systems and technologies, and their interface with the material world.

INSIGHT: *The conception of a cybernetic city carries with it the possibility of information-system-based planning and cybernetic coordination. Cities can be known, planned and controlled in large part through data processes and algorithms.*

In a cybernetic city functions that are kept separate and loosely coupled (e.g. waste collection, transport provision, energy services, security and emergency response) are planned and operated in an integrated relationship. Therein, there is a single, unified information system that accounts for software and hardware systems that interoperate and are interconnected.

NOTE: *In the industrial environment, enterprise resource planning (ERP) systems have been used extensively to coordinate the flow of resources in order to streamline internal operations, linking finance, procurement, payroll and human resources in cities. ERP systems effectively render internal resources relations predictable and controllable. The use of ERP implies a functional understanding of the organization, wherein the division of operations into functions and sub-functions is crucial for the appropriate functioning of the whole. In an ERP system, organizational operations are detailed as a breakdown of components into sites (locations), agents (subjects), functions, and relationships. Note that there are also resource planning systems for various sub-industrial functions, including, for example, manufacturing resource planning (MRP).*

Technology embodies routines and procedures that generate particular forms of perception and cognition, both shaping behaviour due to the processes of functional simplification and reification by which a prescriptive order is formed (Kallinikos, 2011:7). Kallinikos explores different techniques of coding with a particular focus on object-oriented programming. Object-oriented programming is a structured form of software coding, organized by structures and procedures, that divides reality into objects, which are further divided into sub-objects. Each object has attributes, and by recombining attributes the relationships between objects can be reconfigured. This computational logic renders reality as a set of integrated information, and thus, usable in the real world.

Through an emphasis on modularity, along with pre-determined structural features and intrinsic qualities, information technology packages and knowledge are constituted as both specialized and transferable--from or organization to organization or city to city (Voutsina et al., 2007).

A cybernetic city, as a system of systems, operates through techniques of classification, resulting in the provision of a system for organization and, in this way, a framing for an objective reality. This classification process involves the development of typologies, the establishment of system hierarchies and a mapping of connections between these components. Such direct identifying and explication of interconnectedness renders the entire system of internal relations predictable and controllable. Classification also has an ontological function, by determining components and establishing a set of relationships, thus creating entities with definable boundaries (e.g., service inputs, processes, and outputs). The integrated visualization of a city as a system of systems necessarily involves the development of a detailed map for organizational action and control. (Marvin, 2017: 93-94)

Current hardware and software technologies allow for city-scale operating systems. The idea of the city as an operating system has been discussed in the literature. First, it has been used as a 'metaphor' in which cities are seen as interchangeable with computer systems. (Marvin, 2017) Therein, the city is viewed as an information [processing] system based on the acquisition, storage, processing, and retrieval of information and materiality – an operating system. Through these information technology systems, locations and actions are capable of being sensed in real-time, wherein the operating system aggregates and processes data leading to decisions and actions at a distance. (Marvin, 2017). The resulting 'real-time city' operates through sensor networks, computing frameworks, and automated hardware that aggregate data streams into services and products (i.e., fulfillment) for their users (Townsend, 2000; 2015). Further, Easterling (2014: 5) examines how a combination of infrastructure space, sensors and software are may be designed to use information to “determine how objects and content are organized and circulated [in] an operating system for shaping the city”. Easterling (2014:6) describes an operating system as a platform, both updated over time and unfolding in time to handle new circumstances and situations, which uses software ‘protocols, routines, schedules and choices’ to encode relationships between buildings or managing logistics of infrastructures. This later view describes the operating system as a platform for city control. Thus, it is possible to view, understand, and operate a city through an examination of the hardware and software systems that coordinate and control its behavior.

The software components of these systems include, but are not limited to:

- Databases, predictive systems, analytics, modelling and simulation.

The hardware components of these systems include, but are not limited to:

- Computers, sensors, control rooms) assembled into purpose-built platforms for functional and spatial integration.

NOTE: *In practice, these software and hardware systems form a hybrid of techniques, tools, and software systems.*

Responsive city design and operation is not just about the convergence of different technologies, it is also about the convergence of semantic structures (perceived environment and life world) and syntactic structures (services and infrastructures) over time. Thus, cybernetic cities can be viewed from four primary dimensions:

1. **The conceptual cities (1D-cities)** - for example, the conception of a city
2. **Bi-dimensional cities (2D-cities)** - for example, GIS overlay data.
3. **Three-dimensional cities (3D-Cities)** - for example, 3D mesh models of a city’s objects.
4. **Dynamic, spatio-temporal cities (4D-Cities)** - for example, a simulation of the city with mesh models and GIS data over time.

Cybernetic modules for a city system are likely to include at least three principle elements (Costa, 2019):

1. **Instrumentation** - the ability of systems to measure information by means of sensing tools. Instrumentation is the first movement of action against entropy. Examples are locative media (LBM), georeferencing (GIS) and remote sensing. Herein, environmental, energy, and social sensors serve as parameters.
2. **Analytics** - informatics to perceive and interpret acquired information in accordance with a set logic. When a system acts upon information within the information environment to produce more useful information. In city design, parametric methods include: BIM (Building Information Modeling), SIM (System Information Modelling) methodologies, and performance management (PM).
3. **Actuators** - when a systems acts physically within the spatial environment.

NOTE: *Instrumentation and control systems are used to automate processes. Items to be included in the design and analysis of these systems are: reliability of control of critical processes, safety of personnel, and suitability of instruments and control devices in the environment in which they are installed.*

Cybernated habitat data collection sources (terminology) and assessments include, but are not limited to.

1. **Environmental monitoring networks** - Networks that provide data [sources] on environmental variables. For example, weather data, air quality, user health data, etc.
2. **Fixed and mobile sensory arrays** - arrays of sensors, such as those attached to the interior or exterior of buildings, or airbone platforms.
3. **Real-time sensors** - sensors that collect and transmit data to be processed in real-time.
4. **Recorded sensors** - sensors that collect and store data to be processed at a later time.
5. **Distributed sensory networks** - sensors to monitor and collect data on physical phenomena, physical conditions, and physical systems.
6. **Biomonitoring (biological monitoring)** - the assessment of an ecosystem base on organisms living in it. The lives in the ecosystem.
7. **Data contributed by city inhabitants (crowd sensed, social)** - city inhabitants articulate issues and other data.
8. **Global positioning system (GPS) -** data from a satellite-based global positioning system.
9. **User profiles** - the current, check-in, or modification of user profiles.
10. **Habitat assessments** - the assessment of an ecosystem based on its physical characteristics. The physical characteristics of an ecosystem.

The four characteristics of city-level data for a cybernated system (i.e., “big data”) are (Santana, 2017):

1. **Volume:** coming from many data sources distributed across the city.
2. **Variety:** data is collected from different sources, and have structured, semi-structured, or

unstructured formats, such as video records, relational databases, and raw texts, respectively. This is important for cities, because city data is collected from multiple sources.

3. **Velocity:** data processing must be fast and, in some cases, real-time, or it may be useless.
4. **Veracity:** because of the large amount of data collected, and the use of multiple data sources, it is important to ensure data quality, because errors in the data or the usage of unreliable sources can compromise its analysis. In cities, incorrect GPS readings, malfunctioning sensors, and malicious users can be sources of poor data.

2.2 Cybernetic city automated operations control system components

NOTE: *City planning may be otherwise viewed as the pre-programming of habitat [city] functions.*

A cybernetic operational control system for a highly automated city would necessary involve:

1. A project coordination system, including but not limited to:
   A. A tasking system with tasking flow automation
   B. A documentation system with document flow automation
2. A unified information database
3. A unified information coordination system (a.k.a., information management system, IM; e.g., BIM)
4. Continuous system design and development software
5. Models development to control devices and facilities (e.g., buildings)
6. Software and hardware (hybrid) systems to organize, coordinate, and control operations.

The conception of an operational information model of a cybernetic city control system requires solutions to the following tasks. In other words, the following tasks must be solved for the functional conception of an operational information model of a cybernetic city (Kuzina, 2019):

1. **Task 1:** The identification of alternative technical systems that implement the goals and objectives (i.e., a probabilistic decision system).
   A. **Input information:** Tasks and criteria, general requirements for the technical complex (product), the composition of the complex and the requirements for subsystems, the approximate terms of use, the data of scientific and technical information.
   B. **Output:** Principles of design solutions, the required technology and materials, the required solutions and scientific and technical problems, the tree of alternative versions of the technical complex with an assessment of the existing state of availability for each of the options and an assessment of the probability of creating a technical complex to given estimated time
2. **Task 2.** Full assessment of alternative solutions and selection of the solution according to the objectives criterion.
   A. **Input information:**
      1. Product characteristics (for each alternative): static characteristics (e.g., product design specifications, weight, geometric dimensions), dynamic characteristics of the product in different operating modes.
      2. Characteristics of the product life cycle: the required volume of production works for the solution; a calendar date of completion of research, development, production and operation; the duration of the stages of development and production (standards of the times); the economic parameters for life-cycle stages of complex (cost standards).
      3. Criteria and models of the target effect/ outcome.
      4. Model and objectives criteria.
   B. **Output information:** Evaluation of the objectives criterion for each alternative solution; comparative characteristics of alternative solutions for different parameters; reasoning/ justification of the proposed solution.

NOTE: *For this purpose it is necessary to create specialized software that can provide decision support for each task level.*

The composition of a system-wide mathematical and software automated control system operation of the object is divided into 4 subsystems (Kuzina, 2019):

1. **Message/signals analysis system** - determination of incoming information processing modes and providing necessary dialogue between users and technical means. The mode of such messages processing should be determined by the system on particular features of messages. There are five modules (or, blocks) for this system:
   A. **Module coordinator (dispatcher module; 1)** - designed to ensure the joint operation (co-operation) of all units of the message analysis system in accordance with the type of message, the configuration of the system in accordance with the allocated resources, and the implementation of communication with other systems involving mathematical support.

B. **Modules of (2) syntactic and (3) semantic task analysis** — the allocation of individual sentences of messages, checking the correctness of their construction, their distribution, in order of importance, the formation of the summary rules of their analysis, the definition of input and output parameters of the message, the formation of signals in the block dialogue about anomalies identified during the syntactic and semantic analysis.

C. **Module of the works list (4)** - intended for determination of the message processing possibility (transition - from input parameters of the message to output), determination of optimum ways of processing, creation of the list and sequence of works with their necessary description and formation of output arrays structure with their description, formation of signals in the module of dialogue about reception of the message in processing or about impossibility of its processing.

D. **Module of dialogue with the user (5)** - provides formation and delivery to the user of signals about acceptance of the message in processing or impossibility of its processing, about the anomalies revealed during the syntactic and semantic analyses, the analysis of additional (secondary) messages of the user, addressing them in other modules of system and formation of the corresponding signals to the user about implementation of its additional messages.

2. **Information support system for task solving** - The system is designed to organize the storage of information and provide the necessary information to solve all calculation and information problems. The information support system includes 7 modules. Additional modules can be included in the system, such as standard procedures, placement optimization modules, information security, and statistics collection.

   A. **Module coordinator (1)** - to ensure the joint operation of all the modules of the system.

   B. **Module of information requests analysis (2)** - performs the functions of perception, semantic analysis of the request, determining the optimal way of its processing.

   C. **Modules of (3) formation, (4) updating and (5) maintenance of information arrays** (fields) - ensure the compilation of information record structures, the establishment of semantic (associative) links, the compilation of addresses, the location of records, the organization of new data or changes to existing records, the elimination of obsolete records.

   D. **Module of information retrieval (6)** - provides the determination of the location addresses necessary for solving a specific task of information, the selection of information from the corresponding information files, the organization of the primary grouping of information in accordance with the requirements of a specific information request.

   E. **Module of response arrays formation (7)** - determine the form of the response array, which is necessary for solving a specific task, selecting and arranging information in the necessary order, selected and grouped by the search unit, including standard library procedures into operation, which are not explicitly in the main information arrays.

3. **Organization system for task solving** - direct control of a projects (or, programs) set of work including mathematical support at the solution of information and settlement tasks. To perform its necessary functions (*see below*), there are 5 modules:

   A. **Module coordinator (1)** - to ensure the joint operation of all the modules of the system for solving problems, setting the system to work in the mode corresponding to the allocated resources, and communication with other parts of the system involving mathematical support.

   B. **Module for planning (2)** - provides the definition of the resources required to solve the problem and the formation of the corresponding application, the planning work on the solution of tasks when selected.

   C. **Module for task library maintenance (3)** - maintains a library catalogue searches and a call to the required programs, should maintain and update the library and directory.

   D. **Module for control (4)** - ensures the development of the plan of computational work, timely connection to the necessary programs, the formation of appeals to the exchange unit in the case of joint work of several programs.

   E. **Module for exchange (5)** - organizes the joint work of several programs, processing of additional instructions received in the course of solving problems, monitoring the use of allocated resources and the time of return of free resources.

4. **Automatic project coordination/management system** - designed for registration and accounting of all appeals to the system, differentiation of access to information and tasks. To perform its

functions (*see below*) the system has 6 modules:

A. **Module coordinator (1)** - provides for the joint functioning of all the modules of the system in all modes: applications for inputting, outputting information and solving problems from individual external subscribers, technical personnel of the facility, other automated objects of the system, other tasks solved in the system, etc.
B. **Module of message registration (2)** - registers messages.
C. **Module of checking request authentication (3)** - authentication of a request based on unique characteristics of calls (names or numbers of subscribers, various digital, light codes, especially voices, etc.) identifies subscribers and checks their right to Enter, output information and solve problems.
D. **Module of newly formed information classification (4)** - classification (establishment) block of the newly formed information column automatically, based on a meaningful analysis, determines the right (security classification) of different subscribers to use information, which is a synthesis of individual messages or the result of solving problems.
E. **Module of accessing information organization (5)** - prohibits or allows access to information and tasks without the permitting commands of the authentication checker unit, and organize access to information and tasks with appropriate permissions.
F. **Module of registration and information delivery (6)** - registers the delivery of information.

In concern to the information support system (*see above*), to reduce the volume of operations for the preparation and input of information into the system, eliminating unnecessary duplication of work and information, reducing the required amount of memory and unification of mathematical support, it is necessary to create a single array (fields) of information to solve all problems of automated control systems. According to the efficiency of use and physical storage of information single arrays (fields) can be divided into levels (Kuzina, 2019):

1. Permanent information.
2. Operational information required to solve a set of tasks of one stage of management.
3. Current, information needed to solve a specific problem.

The objectives of the information support system include (Kuzina, 2019):

1. Reception, placement and storage of information.
2. Search on information fields and selection of information necessary for solving specific tasks.
3. Processing of selected information, editing and formation of response information.
4. Arrays (fields) in the form necessary for solving specific tasks.

The following requirements are necessary in order to solve problems associated with the necessity for operational information (Kuzina, 2019):

1. Ensuring efficient and optimal use of data, information and all types of resources.
2. Automation of production processes, decisioning processes in the event of deviations from the planned indicators (or, pre-planned flows).
3. Complex systems formation for interaction of production and socio-technical processes.
4. Ensuring information interaction between people and between people-and-machines as a means of communication and information transfer.
5. Development of a learning system, system of knowledge accumulation and information coordination within the society.
6. Predictive analysis of scientific and technological development, forecasting of engineering systems.
7. Risk assessment and calculation of the probable consequences of adverse circumstances.

In concern to the organization system for task solving, the system should provide the following functions (Kuzina, 2019):

1. Specific planning of computational work required to solve task problems.
2. Determination of the necessary system resources to solve a problem.
3. Timely inclusion in the work of some programs of special mathematical support.
4. Monitoring the progress of the task and its logging.
5. Processing and maintenance of additional instructions received in the course of solving a problem.
6. Definition of capabilities and management of parallel solution of several tasks.
7. Modify the plan of solving the problem and the redistribution of computational efforts in the case of changing the allocated resources.

The operation of the automatic project coordination system should provide the following functions (Kuzina, 2019):

1. Identification of the subscriber who has applied to the system for input, output of information or

solution of this or that task;
2. Check the rights of the subscriber to input, the output of this information, and that the solution of a particular problem;
3. The permit input, output information and the solution of the problem or a signal of disloyalty of circulation;
4. Definition of the classification of the newly generated information (the solution of task or generalization of individual messages) on the right of secrecy;
5. Registration of all requests for input, output information, problem solving with indication of subscribers, time entered or issued information.

The requirements of a software system for the operation of the prior detailed automated control system, which can take an effective final decision, include (Kuzina, 2019):

1. Database containing data of statistics reports, goals and requirements of the users of projects.
2. Software modules for collecting information, importing data into the repository by both automated and manual input that depend on the required information and its source, modules for calculating performance indicators and comparing options.
3. Analytical subsystem of standards, infrastructural elements, suppliers of materials, equipment, etc.
4. A planning subsystem for predicting the results of selected solutions, based on the calculations of local problems, which performs calculations in the form of comparison.
5. A means of visualization of the obtained multi-factor parametric models. Means of display of initial data at the stage of information input, results of changes of the main criteria depending on the chosen decision for each parameter, results in General on object. Generation of reports in various formats.
6. An administrative subsystem is necessary to ensure information security (taking into account the differentiation of access rights to information, the order of use of data libraries), to work with database servers.

In addition, the usage of an information system for coordinating the operation of buildings and their infrastructure will allow (Kuzina, 2019):

1. Improve the efficiency of design, construction, operation on the basis of predicting the behavior of the building system and its infrastructure.
2. To organize rational management of the project implementation by increasing the level of operation planning at the initial stages of design and increase efficiency in the implementation of tasks.
3. Build a predictable financing system for the facility throughout the life cycle of the building, simulate changes in infrastructure projects.
4. Reduce time for preparation and execution of works, labor costs for operations on search and processing of data for decision-making.
5. Provide the proper level of security in operation of life support systems in smart city.

Additional requirements for the implementation of a cybernetic city system include, but are not limited to:

1. A universal coding system (or, universal code) for the unique identification of all recorded knowledge and information. The designation of an information system designed to provide global access to all knowledge and information. All material identified by this code can be located by the use of a multi-category index. These categories include, but may not be limited to: (1) subject terms and phrases, (2) proper names, (3) geographic names and places, areas, or segments, (4) type of material, and (5) level of material. (Lasker, 1981)
2. The software for all habitat service systems.
   A. An information system to account for all planning and operational activities at any given time.
      1. Systems to collect, analyze, model, optimize, and visualize operations of city systems.
      2. The software architecture to monitor, process, translate/control, and communicate city and human data.
      3. Information software to acquire and understand environmental data for livability.
      4. Information software (decisioning) to determine optimal materializations from knowledge for resilience.
      5. Information software processes (communication) to translate information to users for sustainability.
3. The hardware for all habitat service systems.
   A. The hardware architecture to monitor, process, translate/control, and communicate city and human data. For example, sensors to sense economic information from users; sensors to sense environmental and ecological information; hardware Systems to computationally process data.

2.3 The network of cities

A.k.a., The cities network, the city network, the geometric network of cities, the global network of *cities, the global city network, the community-city network, the city-community network, networked cities, the city system, polycentric urban configurations.*

A city network is a specific type of spatial structure formed through the combination of city agglomeration and connection within and between cities. (Ni, 2017) A community-type societal system is materially composed of a network of integrated city systems that operate together to create a unified, global habitat service system (i.e., a single, global economic/access system). In community, there exists a global network of cities (i.e., a global city network, or global cities network). In other words, said society materializes as a network of integrated city systems that operate through a unified, global habitat service system consisting of all the cities in the [community] network. Cities in community are set within an enormous, global city network connected by the various flows of information and materials.

NOTE: *Cities in a community-city network are both independent (in that they are self-integrated) and interdependent (in that they share access to resources and services).*

Cities in a community city network are unified under a single societal information system. Therein, the network of city systems is represented by the Global Habitat Service System (a.k.a., a true global access system), followed by the local city systems, represented by the Local Habitat Service Systems. Simply, there is one global conception of a service system for global design and accounting, and then, there are many locally materialized city expressions.

NOTE: *The total material system of community operates as a united network of cities with shared, coordinated access to global resources and services.*

An analytical framework for a city network must account for:

1. Centrality (intra-city development) - the design and development of a single city; .
2. Inter-connection (inter-city development) - development and access between cities.

Note that the market-State defines a network of cities as two or more previously independent cities that work toward jurisdictional and/or economic "cooperation" to achieve faster and more reliable trade, transport and communications infrastructure. The evolution of cities in the market-State is toward a network of jurisdictionally interrelated cities that trade with one another (i.e., "trading cities"). (Batten, 1995)

INSIGHT: *A city network can distribute the load of production.*

Further, in the market-State, State/jurisdictional relations and political situations determine whether there is a weak or strong socio-political connection between cities. Therein, global socio-political situations and changes play a significant part in the remodeling of cities, thereby affecting the jobs, wealth, mobility of occupying inhabitants (e.g., mass migration due to unrest in other geographic locations).

2.3.1 The networked grid of cities

A.k.a., The grid of cities, they city grid network.

Generally, cities in community are laid out in a geometric grid-like manner. When viewed from above, cities in close proximity to one another in a community network of cities are often seen to be laid out in a geometric arrangement, wherein individual cities are located at the vertices ("points") of whatever shape the geometric grid of the arrangement takes. For example, cities could be laid out in a hexagonal-like grid structure with cities at each vertex of the repeating hexagonal shape, wherein the transportation network between cities is placed at the edges of the repeating hexagonal shape. In other words, when zooming out from an integrated city systems, there is a visible return to nature before a network of such cities appears in geometric formation, and possibly, clustered.

NOTE: *Each city in the community network is part of a unified community [habitat service] system, and connected via a mass rapid transportation system.*

Frequently, the total global city network is divided to city clusters, wherein many cities are clustered in geometric proximity to one another. However, this clustering arrangement is highly dependent upon geographic region, with clustering not being possible in some geographic regions.

2.3.2 Fulfillment profiles

Cities in community could be viewed as "fulfillment centers". Therein, if "you" don't like a particular fulfillment center (i.e., a particular city), then there are other cities in the community network that may resonate more greatly with "your" fulfillment profile.

2.4 City surface mediums

On Earth, there are presently two surface mediums for city construction:

1. Land-based cities - cities positioned on land.
2. Ocean-based cities - cities positioned on bodies of water.

A global network of cities in the sea can easily accommodate many millions of people and relieve the land based population pressures. On the ocean, ships could act as integrated manufacturing platforms producing products as they travel.

2.5 City structuring

> **NOTE:** *The following descriptions attempt to be societally agnostic.*

There are three primary types of city structure:

1. **The radio centric city** - Radiates outward from a common center. Inner and outer ring roads are linked by radiating roads. A direct line of travel for centrally directed flows. A radio-centric city does not have to be a circular city; a square or other shape can also be laid out as a radio centric city. Moscow, for example, is a radio-centric city, with the center of all rings being Moscow Kremlin and Red Square.
2. **The gridiron city (rectilinear)** - Composed of straight streets crossing at right angles to create many regular city blocks. This form is typical of cities built after the industrial revolution. Requires flow hierarchies. Is potentially monotonous. Flexible grid expansion.
3. **The linear city** - A city expanded along a linear transport system. Very sensitive to blockages. Uni-dimensional linear expansion. Dubai and Navi Mumbai are examples.

The most well-known models of city land growth include:

1. **Concentric model** (concentric zone model, Burgess model) - city grows radially outward from a single point. Ideally, different land uses are distributed via concentric rings around the city center.
2. **Sector model** (sector zone model) - city grows sector by sector.
3. **Multi nuclei model** - city grows from several independent points rather than from a central area. Little to no planning; almost completely ad hoc.

In the market-State, rectilinear cities have several advantages and disadvantages given those conditions (Levinson, 2020):

- Advantages include, but are not limited to:
  - Maximizes the use of space for square/ rectangular buildings.
  - Simplifies real estate by making market-State surveying easier.
  - Is embedded in existing property rights, effectively making the property rights structure [nearly] impossible to change.
- Disadvantages include, but are not limited to:
  - Is among the least efficient way to connect places from a transportation perspective.
  - Reduces opportunities for nature, interesting spaces, architecture, etc.
  - Wastes developable space by overbuilding roads.

The market-State urban population-dimension hierarchy generally scales in the following manner:

1. **Hamlet** - may only include a few dozen people and offer limited services. These are clustered around an urban center and may only consist of basic need services.
2. **Villages** - larger than hamlets and offer more services.
3. **Towns** - more urban with a defined boundary, but smaller than a city in terms of population and area.
4. **Cities** - densely populated areas that may include tens of thousands of people.
5. **Metropolis** - large cities and their suburbs.
6. **Megalopolis** (conurbation) - where several metropolitan areas are linked together to form a huge urban area.

In concern to sustainability, the key design issues in city structuring include, but are not limited to (Marshall, 2005):

1. The need to create layouts that minimise the demand for energy and materials.
2. The need to create layouts that eliminate the automobile, while facilitating walkability and utilizing mass rapid transport.
3. The need to use environmentally friendly modes of transport, especially walking and cycling (which may also bring health benefits).
4. The need to space service locations appropriate to demand.

The divisioning of districts/zones in a city occur based upon (includes, but is not limited to):

1. **Demand** (i.e., # of people; mass and volume of demanded objects)
2. **Service type** (e.g., business, residential, recreational, etc.)
3. **Access type** (e.g., personal, commons, system)
4. **Location and proximity** (of people to goods and services)
5. **Socio-economic class** (market only; e.g., high-income class, middle-income class, lower-income class, poverty class)

It is relevant to note here that many of the ongoing early 21st century theories around city design and development are marred by presumptions based on outdated understandings, poor quality data on humans' real-world requirements, and dis-unified modeling.

Central place theory, for example, is a market-State geographical model of the spatial distribution of cities across a landscape that sought to explain the number, size and location of human settlements in a residential system, and was developed in 1933. (Ben-Joseph, 2000) (Pumain, 2004) The theory was created by the German geographer Walter Christaller, who asserted that settlements simply functioned as 'central places' providing services to surrounding areas. (Goodall, 1987) (*Central place theory*, 2019)

The sub-conceptions of central place theory are [out-dated and market-focused]:

- **Central places** - urban centers that provide services to their surrounding rural people (hinterland).
- **Threshold** - the minimum number of people needed to support a particular function's existence in a central place. Including, the minimum number of resources and tasks required to maintain a particular function's existence in the city. The more unique and special an economic function, the higher the threshold.
- **Range of good or service** - the maximum distance a person is willing to travel to obtain a good or service. And, the maximum distance at which a good or service may be accessed. How far is a consumer willing to travel? Central place theory assumes consumers will not be willing to travel as far for lower central place functions. What if the consumers may no longer need to travel because the transportation system now delivers?
- **Spatial competition** - central places compete with each other for customers. Central place theory assumes central paces will be located farther away from each other, because consumers are more likely and willing to travel a longer distance to obtain higher central place functions.

2.5.1 Circular city naming

A.k.a., 2D Circular grid, radial grid/plot, polar grid/plot, hemisphere mesh, circular layout, circular or polar graph.

A circular city has the following identifiable elements (Hakan, 2020):

1. **Circle** - A circle is the path traced out by a point, moving in a plane, that is always a fixed distance (the radius) from a fixed point (the centre).
2. **Center** – Location of the grid origin, [point]
3. **Central area** - area of central most circle. The formula for the area of a circle is:
   - $A=\pi r^2$
   - Wherein, A = Area; π = 3.14...; r = radius
4. **Inner** – The inner radius of the grid, [number]. Radius of inner circular sector.
5. **Outer** – Radius of the grid, [number]. Radius of outer circular sector (radius of city boundary).
6. **Sectors** – Sets the number of sector dividers, [array]
7. **Rings** (belts, circulars) – Number of concentric dividers of the grid, [number]

The parts of a circle are (*The circle*, 2011):

1. **Radius** - A radius is any interval (or line segment) drawn from the centre of a given circle to any point on the circle is called a radius, (plural radii).
2. **Diameter** - A diameter is any interval joining two points on the circle and passing through the centre is called the diameter of the circle.
3. **Semicircle** - A diameter divides the circle into two congruent parts. Each part is called a semicircle (2 total semicircles to a whole circle).
4. **Quadrants** - If a radius is drawn perpendicular to the diameter in a semicircle, there are two congruent quadrants (4 total quadrants to a whole circle).
5. **Sector** - Any two radii divide the circle into two pieces. Each piece is called a sector (from the Latin word secāre − to cut).
6. **Circumference** - The distance around a circle.

There are a variety of different layouts of circular city, including but not limited to:

1. **Concentric** - denoting circles, arcs, other shapes that share the same (com-) center.
2. **Overlapping** - denoting circles, ars, other shapes that overlap.

2.5.2 City layouts in community

A.k.a., City shape, urban pattern.

Most cities in community are of a circular arrangement (a.k.a., radial-concentric, ring-radial, circular radio-centric, or polar coordinate configuration) with the central area acting as a representative centerpiece of that particular city. There are non-circular cities, some of which are non-circular because the geography won't allow for a fully circular configuration. Cities aren't generally built on a flat surface, even planned cities have to work around natural features in the terrain; that is, to the degree to which the site has been appropriately selected and the terrain is capable of being modified. The circular city is simply a theoretically "optimal" design, local topography and geography will, in many cases, change the design slightly.

NOTE: *Living organisms have bi-lateral symmetry. If the city is viewed as a living organism, then it may be designed with bi-lateral* *symmetry (i.e., city symmetry).*

The proposed circular configuration of many of the cities in community is not a just stylized architectural conceptualization. It is the result of reasoning and evidence into providing an environment that can best serve the needs of the inhabitants and conserve resources. The circular arrangement effectively permits the most sophisticated use of available resources and construction techniques with minimum expenditure of energy. The efficiency of the circular design allows us to make available to all people the most advanced amenities that our knowledge and energy can provide.

A circular city is most practically divided via pathways into areas known as [radial] sectors and circular belts (a.k.a. "circulars" or "rings"). The radial sectors (separated by pathways) are subdivided by circular belts (also separated by pathways), which extend outward from a central point, forming a widening circular grid structure. As the circle widens, more circular belts follow until the perimeter is reached wherein the environment is allowed to return to wild nature without any form of sprawl. In other words, these circular cities are composed of a central area beyond which the geometry takes the form of radial sectors and circular segments. In most configurations, there is a differentiation of primary functioning between belts (and sometimes within segments of a belt itself). In other words, each circular belt (and/or radial segment) maintains a particular set of functions, some of which will be unique to that circular belt and will give the belt its name. Other functions are shared between belts. The core function of the recreation belt, for example, is to provide recreational services and structures. Secondarily, however, the recreational belt maintains permacultural land and aquatic spaces for the growth of food and natural beauty. Although every circular belt will have a core identifying function, all belts are multi-functional.

There are a variety of reasons why a circular city scheme is more efficient than other city layouts. Firstly, when you start at one point on a circle, and move along that point, you eventually come back to the same point. When it's a linear city within which you are moving, you have to travel back again (i.e., backtrack) over the same area [instead of just going around). Hence, when traveling within a circular city someone could easily return to the same place from where they started without having to take the same route back, as is the case with most linear cities. Secondly, circular designs place frequently used facilities (mass transit, medical, and other common access locations) near the center. This puts most of the residential population very near (in time and space) to the city center, and ensures that travel throughout the city is relatively easy. Hence, no matter where you are in a circular city, you would be within a reasonable distance to access every facility the city has to offer. A circular shaped city ensures that no [access] point on the circle is ever further away than half the circumference of the circle itself, which is an important design consideration for emergency response. Conversely, a squared shape maintains that no point is further from another than the "Manhattan-distance" (i.e., the distance between two points, as 90° horizontal and vertical paths on a square grid; versus an acute diagonal(s) with a circular grid). Fourth, a planned circular design minimizes the length of all transportation and distribution lines (in comparison to a linear design) -- less to build, less to maintain, and hence, more efficient. Fifth, consider that a grid inside a circle would combine the advantages of best use of space with a most understandable addressing system. Of course, either a square grid or circular grid are better than a random or disorganized configuration. A circle, however, provides the most efficient form of infrastructural elements required for its outside perimeter. Only 1 shape of interlocking element is required over 2 shapes (straight and right angled) for a square. Sixth, the circular design allows for one "pie-like" sector of the city to be designed, and then replicated around the circle six to eight times (with slight adaptations for functional differentiation) to form the entire city. In the design and production of a circular city we work out 1/6th or 1/8th (for example) of the city system, and then we reproduce it around a central point. The replication of a radial sector around a central axis (returning to the original sector itself) uses fewer resources than conventional construction methods for linear cities. In market terminology, these cities are extremely cost efficient because only one radial sector needs to be designed, which can then be duplicated repeatedly and slightly versioned for the completion of an entire city. Seventh, a circular layout is easily replicated at different scales. These cities can be designed for a couple hundred people, or scaled up to population sizes of 100,000 or more. And finally, at least for this discussion, the circular arrangement is also a useful geometric design for mirroring natural symbiotic cultivation cycles. Circular symbiotic farming, for example, is often applied as part of the last circular belt of these cities.

In general, a well-designed and aesthetic circular city tends to feel more harmonious and open than its equivalent as a linear city. We do live on sphere (of sorts), and from a two dimensional perspective the planet upon which we live takes the shape of a circle. It may be further interesting to consider that our eyes, the stars in the sky, including our sun, and the moon are also all circular in shape. Even our galaxy has a circular symmetry. It may be interesting to consider that the motions of nature move in spheres and rings, and all cosmic bodies seem to move in spiralling arcs.

The round architectural shape of a circle provides a natural sense of unity. Historically, it has also been a practical form of defense against dangers coming in from all sides. Further, the circle is one of the emblematic tools to express one-ness in a visible environment. Corners break the non-hierarchy of unity. All planets and suns take the shape of a circle. There is clearly a connection between central planning (optimal socio-technical organization), the search for unity (optimal information organization, and the shape of a circle (optimal structural/geometric symmetry). (Delen, 2016)

The relative current scarcity of circular cities on the planet in the early 21st century can probably be explained by considering two causes. Firstly, the prerequisite for a circular city is a suitable geography (the natural factor) and a deliberate plan to continue city development along concentric lines (the human factor). Ideally, the round city is situated on a plane (or terrain modified environment) without significant natural obstructions. Such natural areas are common all over the world, but there are, nevertheless, very few circular cities that are built in those natural, ideal geographical areas. Hence, the absence of circular cities on a wider scale must have another reason, which is likely found in the human factor. It seems that people in power are not interested in the idea of circularity and its inherent neutrality. The combination of a strong government, which can implement ideas by force versus a non-hierarchical message of the circle-in-general is an dissonant one. Powerful governments, based on a vigorous application of law and order, are hardly ever the keepers of peaceful ideas. The main reason is, that otherwise they would not be in command. (Delen, 2016)

> *"The preference of the circle as an architectural feature is the result of a resistance and opposition against squareness. However, the circle is also – in a non-oppositional ambiance – the beginning (or end) of a path of insight." (Delen, 2016)*

The growth of most cities in the 21st century is the result of ad-hoc market and political decisions. The concentric design needs a deliberate planning in a fairly unprejudiced setting. Rapid urban developments have no time for the relative forethought of a circular configuration. Such types of city layouts only come into being under special (i.e., thoughtful) circumstances. (Delen, 2016)

Continuum approximation (CA) optimization models can be formulated and tested to design an optimal city-wide transit system with correlation to optimal city layout. Chen (2015) used two models for comparison. Model 1 assumes that the city streets are laid out in ring-radial fashion. Model 2 assumes that the city streets form a square grid. Therein, Chen et al. assumed transit routes lie atop a city's street network. Model 1 allows the service frequency and the route spacing at a location to vary arbitrarily with the location's distance from the center. Model 2 also allows such variation but in the periphery only. Chen et al. shows how to solve these CA optimization problems numerically, and how the numerical results can be used to design actual systems. The results show that Model 1 is distinguished from Model 2 in that the former produces in all cases: (i) a much smaller central district, and (ii) a high frequency circular line on the outer edge of that central district. Parametric tests with all the scenarios further show that Model 1 is consistently more favorable to transit than Model 2. And, cost differences between the two designs are typically between 9% and 13%, but can top 21.5%. This is attributed to the manner in which ring-radial networks naturally concentrate passenger's shortest paths, and to the economies of demand concentration that transit exhibits. Thus, it appears that ring-radial street networks are better for transit than grids. (Chen, 2015)

2.6 City expansion

> **INSIGHT:** *What is a tumor? A tumor is a growth untethered to the consequence of it growing; a growth for its own sake, otherwise known as a suburb. A suburb is a type of societal tumor.*

Individual cities can grow in three ways:

1. **Outward** - expanding horizontally.
2. **Upward** - expanding vertically.
3. **Toward greater density** (a.k.a., densification, in-fill)- expanding interstitially (i.e., filling up every free space and reducing the space available for inhabitants); often the least pleasant for inhabitants.

The market's solution to overcoming population congestions is, most often, to spread out horizontally. All early 21st century cities have done this (i.e., spread and sprawled outward), only to create more problems. Moreover, expansion is generally not uniform, making the problem of transportation even more complicated. This has come to be known as urban and sub-urban sprawl.

Cities in community are designed with a planned, specific carrying capacity. When a city hits a certain size, it stops and mostly thereafter, everything is allowed to return back to nature between this and the next city; there is no urban sprawl. The iterative design for a city in community is "organic" to the extent that new information evolves the system; but, its operation is planned, and so, there is no sprawl (i.e., no "suburb") or haphazard/chaotic development (as is the case with the "organic" development of nearly all prior cities).

> **INSIGHT:** *To "suburbia" a society leads to the separation of the individual from a place of meaningful effort, meaningful relationships, and meaningful results. Do you live in a suburb? Is it considered acceptable to randomly hug your neighbour?*

Cities in community are not meant to be ever expanding, as is the case with early 21st century cities and suburbs. Instead, circular cities can be reconfigured internally, but the diameter is mostly fixed. Instead of expanding cities horizontally (i.e., over the surface medium they are built upon), a new city is created nearby and connected by a transportation network so that nature is left between cities. Community cities can be iterated and updated internally, and also expanded vertically, but they are not intended to be expanded in surface area coverage.

It is true that squares can be more easily compacted [next to one another] than circles, but when designing city systems for community, beyond the perimeter of the city, the environment is allowed to return to wild [caretaken] nature. So, whereas a linear or squared city would just continue to add more blocks/modules [to itself]; instead, community would allow a return to nature prior to the creation of another [circular] city. Note that the one exception to this rule may be extreme desert environments where there is little to no life beyond the perimeter of the city.

> **NOTE:** *In community, we don't want indefinite [city, economic, or otherwise] expansion on our finite planet. In general, when a city reaches carrying capacity, another city will be built, separated by nature some calculated distance away from the prior.*

A city with square blocks can expand indefinitely by placing another block next to the prior, while a city with a single circular block cannot do so with compact geometric alignment. A circular city is one circular grid reducing to a central axis. Of course, if a circular city requires expansion for some reason, it is still possible to do so with geometric alignment by extending the city radially, segment by segment.

2.7 Circular city assembly

There are two basic ways to assemble a circular city (note that these two ways can be mixed):

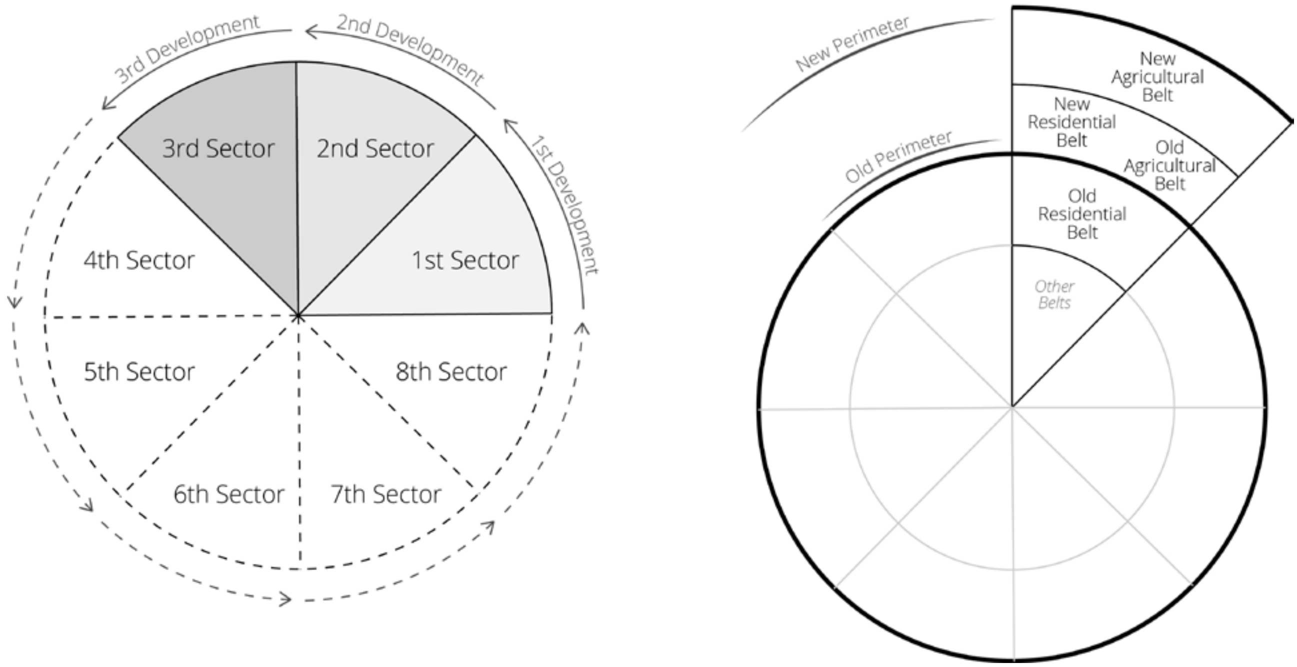
1. Radially - radial segment by radial segment.
2. Circularly - circular belt by circular belt until the planned perimeter is met.

Note that if circular farming was used on the outer segmented belt during the city's phased construction, the soil base could be built up as the city was assembled (belt by belt) to its planned size. For example, originally the city may have only have three circular belts constructed with planned eight. The third circular belt of the initial construction could a circular farm, which would build up a soil base on that belt. When the next belt is added, the circular farming is moved to the fourth belt, and so on. This would obviously create a more lengthy time frame for the construction of said city, but the result would be a higher quality soil base for all belts where circular symbiotic farming was applied.

2.8 Computational and mathematical modeling for cities

Data acquisition and 3D modeling has enabled the dynamic modeling of physical phenomena, objects, and human behavior, including the simulation of complex environments and problems. Computational models can be applied to almost every aspect of city design, decisioning, and operation. Therein, computational models require relevant data and are used to produce indicators for decision support by each subsystem of

Figure 23. *Figure on left shows city expansion going sector by sector over time. Figure on right shows sector-ring by sector-ring over time.*



a habitat service system. Additionally, computational models and their associated software are necessary for optimization, improved design and decisioning. (Stjepandic, 2019)

Computational modeling is fundamentally related to mathematical modeling. A mathematical mode of a the human domain is a formal representation of individuals' attributes and/or desired requirements of a design. For instance, the definition of values and their encoding (transformation) into decisioning is significant for design. Mathematical modeling allows for precision, which can be used to achieve traceability, robustness, certainty, and better rapport with reality. Further, a mathematical model of the functional domains of a habitat service system would represent those functions formally. A formal representation of functions is a prerequisite for representing functions in computers. A mathematical model of the behaviors represents formally the behavior of the physical model. Wherein, the mathematical model of the physical domain is a formal representation of physical variables, design principles and physical principles of the design of a city. (Stjepandic, 2019)

INSIGHT: *We must operate within the carrying capacity of the city as we do similarly within the limits of the earth itself.*

2.9 Evolution and appropriate habitat design

There exist three general evolutionarily-oriented principles for habitat [re-]design:

1. Constant habitat features: If there was some habitat feature that was constant during all of a species evolution, then it must be accounted for in the habitat's design. Take gravity for example, humanity has never known life any other way. If gravity is altered significantly, or it isn't there at all, then the organism will start to face some very serious issues, such as bone density and functional strength - this is seen in space.
2. Cyclical habitat features: Some habitat features are cyclical, like night and day. In the case of a cyclically variable habitat feature it is possible to modify it with a degree of deviation and to the extent that the organism is adapted to it changing. But, if it gets completely out of cycle, out of sync, or becomes monotonous on one side or the other, then the organism is likely to experience dis-ease - this is seen on submarines and with shift-work (where shift workers experience high rates of cancer).
3. Variable habitat features: If a species evolved for much of its evolutionary history with a variable habitat feature [within some bounds], it is probably adapted to that feature remaining varied. So if you have temperature with a dynamic fluctuation through the seasons, or through the days/nights, or maybe the surfaces that the organism moves on varies, and things become too monotonous, then the organism is likely to start experiencing dis-regulation. Variation can be healthy and present adaptive advantages. For example, the night environment is colder than the day environment, which facilitates sleep onset and a lack of waking during the night.

The human body is dysfunctional in certain environments. It is not adapted to certain environmental structures, and it maladaptive to others. And, without knowledge and a realization of the environmental territory into which one is entering, or being conditioned, an individual could kill oneself or cause serious harm to the continued optimal functioning of its organism if it doesn't account for its principle redesign (qualified by a hermetic stress response to prevent fragility).

INSIGHT*: In the natural world, adaptive structures are the result of conscious self-organization.*

3 The life radius

A.k.a., The human life movement space.

A city is essentially a demarcated material 'life radius' within which a population sustainably controls environmental variables and optimize human fulfillment. Individuals spend the majority of their time in the same places, and that environment dictates how easy or difficult it is to make healthy life choices and express one's highest potentials. The term "life radius", itself, describes the space where a population spends the vast majority of their lives (~80 - 90%). To clarify exactly what a life radius is, someone might ask themselves, What are the places I walk to and through on a daily basis? In this life radius are the spaces and places frequented on a regular (e.g., daily/weekly) basis.

> **CLARIFICATION:** *A 'life radius' is a place where individuals spend approximately 90% of their current life.*

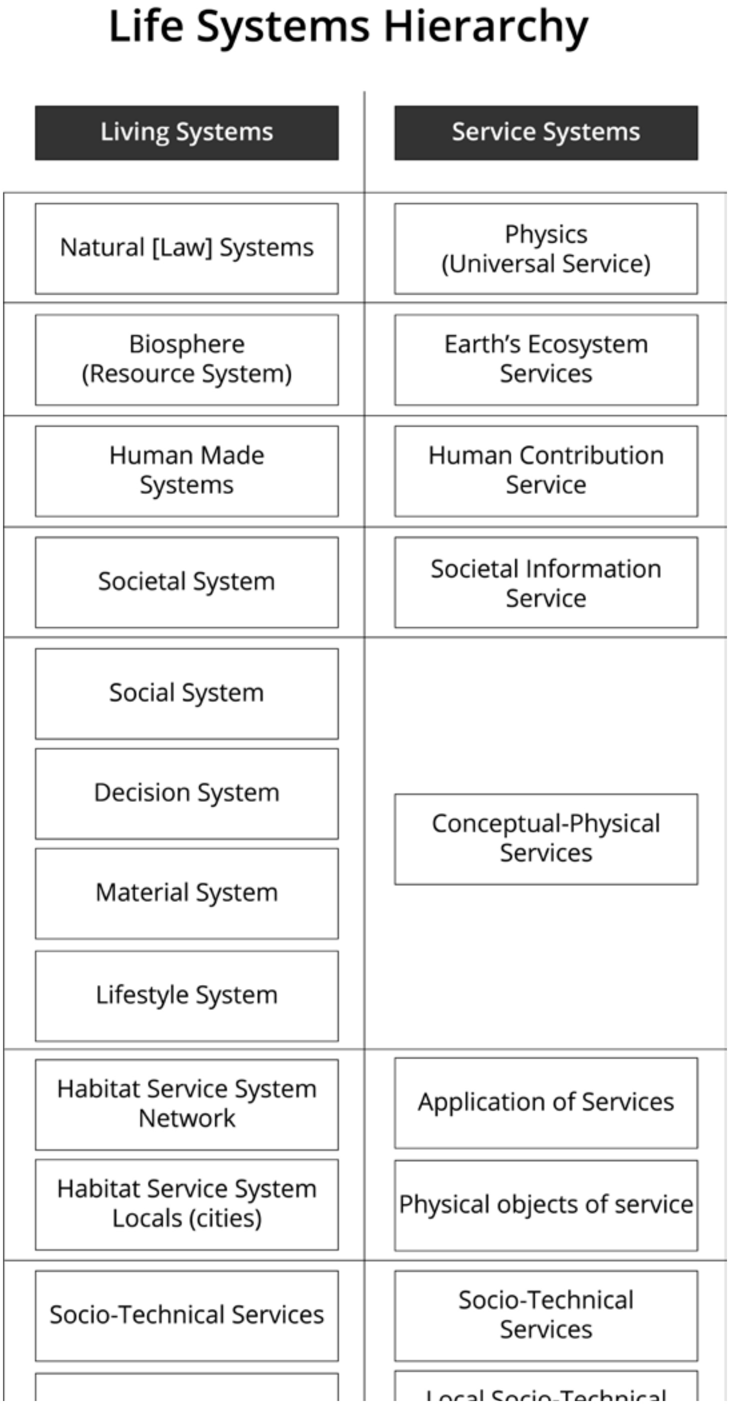
Everything that occurs within the life radius is considered to have an impact on everything else, making it possible for an aware population to control and optimize for their fulfillment within that life radius.. When individuals have to drive a car, that radius can be quite large. But, the ideal life radius is much smaller than city arrangements where cars are necessary. In community, cities are designed at a scale based upon the human being, and not the motorcar or some abstraction. To clarify exactly what a life radius is, someone might ask themselves, What are the places I walk to and through on a daily basis?

> **NOTE:** *Individuals [are likely to] entrain to their environment. If individuals live in a depressed environment, they are likely to be depressed (or, become desensitized to the depression). If individuals live in a happy environment they are likely to be happy, and become sensitive to the happiness of those around us.*

Community is designed in a people-oriented way. The average human being walks two kilometers in approximately twenty minutes. What if that two kilometer walk was beautiful, attractive, safe, enjoyable, and an individuals could meet their needs, contribute, and develop themselves, with others who are doing similarly. A bicycle extends the radius, or makes movement in the radius more efficient. Certainly, a bicycle or mass rapid transport system has a potential of extending what may otherwise be the ideal walking life radius. But, the point is that "you" want most of the things "you" are going to do, for some large percentage of "your" time, to be inside that radius. Having access to what is needed within a walkable radius is strongly correlated with well-being (happiness).

Think about your own life for a moment, where do you work, where are your friend's homes, your enriched

Figure 24. *The societal life systems hierarchy of a community-type society. The left column contains systems that are dynamic and feed back into a total human life system. The service systems in the right column provide the informational and physical generations (material relationships) that complete human material requirements.*



gathering and relaxation spaces, and the locations that produce and distribute your material necessities? Of those key things that compose your life radius, how many can you access by foot or bicycle, and is the experience safe, comfortable, and enjoyable.

> **INSIGHT:** *It is possible to make the healthy and "right" choices the easy ones, with appropriate challenge and preference layered in.*

In community, the life radius is designed to:

- Generate a social and economic decision structure, an environment, where it is it easier to get up and move, eat healthy, make new friends, find a reason for being, and live longer, more optimized lives.
- Create an environment where people move naturally each day without thinking about it. Community makes it pleasant and enjoyable to leave ones dwelling and participate in activities.
- Facilitate healthy food choices while bringing attention to foods that are more nutritious (and hence, flavorful).
- Support personal interconnectivity—between individuals and community activities, teams, and groups.

> **INSIGHT:** *Historically, cities grew because more people move to them than died inside of them.*

3.1 Moveability / walkability

The more thought responsive the world becomes (due to technological automation), the less individuals technically have to move their bodies. And so, humanity might as well design its city environments so movement is intrinsic and facilitated.

3.1.1 Needs versus inculcated expectations

In concern to city design, the question must be asked, Do we need to drive anywhere in the city? Certainly a city population has a need for transportation (personal locomotion, mass locomotion, and emergency locomotion), but is there a need for transportation via cars within the city boundary. It is possible to design and plan a city environment so no one needs a car. It is possible to create walking garden cities where walking and biking are the primary form of movement, and where vehicles are used for emergencies, mass rapid transportation, scenic transportation, and automated distribution functions (e.g., delivery robots).

4 An example integrated city system

Generally speaking, at the level of the material architecture of a human community with a sufficiently large population, and access to digital information technology, are circularly configured walking-garden cities. As we zoom out from one of these cities we see a branching network of cities, each separated by nature. Different cities in the network may display different functional configurations and architectural aesthetics, although they are all still based around a unified community information system. While many of the cities in the network would be circular, others may be linear, underground, or constructed as floating cities in the sea.

This example will first start with a description of the center of the city and work my way outward through the different circular belts. Take note that the stylized elements of buildings and areas in these cities can be customized to the preferred and traditional cultural aesthetics of the local geographic population. For example, buildings in a community-city in China, Japan, India, Europe, the Americas, Africa, or the Middle East may have stylized design elements traditional to those locales.

The following is a hypothetical example. Herein, the land area belts of the circular city are operationalized under the service of a habitat system for functional differentiation. Each belt is a spatial boundary allocated to a different functional service. Between the belts there are circular pathways, and positioned radially around the circle are radial pathways.

4.1.1 The central area

The first area of the circular city arrangement I would like to point out is the city's center; its central access point. Here in the center of one of these circular cities you may find medical care, conference centers, exhibition and art centers, and a whole host of other spaces where social interaction occurs. This central area may also be a transportation hub if the city includes a mass rapid transportation system. Note that if medical facilities are placed in the central hub, then you are never further away from receiving medical care than if you were in the same belt in another sector of the city, which is an important consideration for an active and playful population. And of course, under other city configurations the central area may not have any buildings, but instead it may be a garden for common gathering and natural beauty.

4.1.2 Permacultural gardens

Moving out from the central area, this configuration [we are imagining] has permacultural and aquacultural walking gardens and parks. These are beautiful landscapes organized for food cultivation and aesthetic relaxation. As you walk through them fresh food is available seasonally for harvest, and there is ground for playing and contemplation.

4.1.3 The habitat systems service sector (InterSystems Operations Sector)

The next circular belt out is mostly composed of buildings used for the completion of work relevant to the continuity of the entire city system (it is more commonly known as the InterSystems Operations Sector). These buildings house access hubs, maintenance and operations facilities, as well as research and production spaces. Here, we primarily complete work which updates and cycles services and technologies through the city. All belts are multi-functional, and so within these buildings there are also many common access spaces for a wide variety of technical- and creativity-oriented activities.

4.1.4 Recreational area

As we move away from the service belt we come to the recreational area, which has courts, gyms, and all of the games and recreational activities that people require, amongst beautiful terrain and landscaping. This belt has art centers, theatres, and various spaces for practice and entertainment. There may also dining facilities here, and other amenities.

4.1.5 Low-density house dwelling area

As we move outward, again, we come to the low-density dwelling and housing area where there are winding streams, ponds, waterfalls, and lovely gardens throughout, giving each dwelling a view of beauty and a feeling of being at restorative peace with the world. The residential area of the city continues the idea of coexisting harmoniously with nature. All of the houses are similar in their modern rounded design, but at the same time are very different. Their uniqueness is a reflection of the owner's personality and desired functioning of the home. The architectural elements of all dwellings are flexible and coherently arranged to best serve individual preference. The features of all dwellings in the city are selected by the occupants themselves.

In between every home are natural barriers like bushes and trees, isolating one from another with lush landscaping. So, people who prefer to live in houses and maintain gardens may prefer to live in this area.

4.1.6 High-density dwelling

The next belt we come to primarily functions for high-density dwelling. Its dwellings are for those who prefer apartments. The reason some people may want to live in an apartment is because the apartment buildings themselves have a large number of services built into the tower, providing immediate and close access for those who might want that sort of dwelling placement. People who choose to live in apartments may prefer a more socially dense dwelling arrangement. These dwellings are also above the ground, and so, they provide beautiful views of the city and the surrounding natural environment.

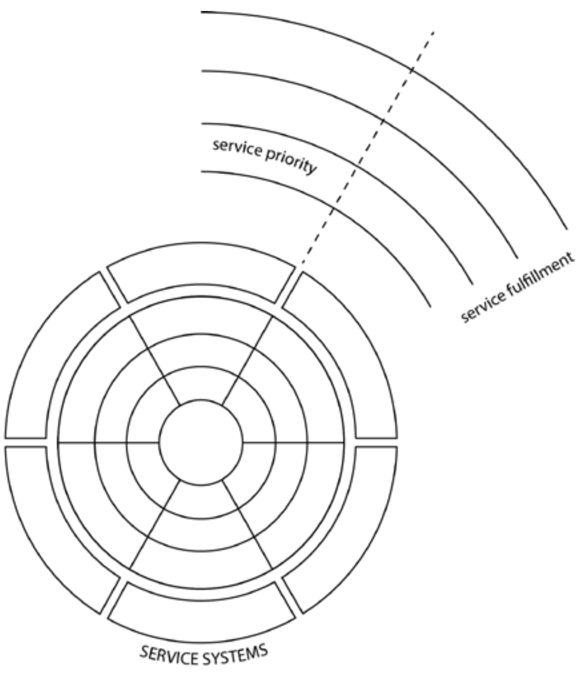
Secondarily, this belt maintains energy production systems, as well as lovely gardens and relaxed common gathering areas.

4.1.7 Water channels and controlled cultivation

Passing out of the high-density dwelling belt on our way to the outer ring of the city we come to the primary food cultivation belt in-between two water channels. On the food cultivation belt we organically grow a wide-variety of plant and insect species, both outdoor and inside greenhouses. Here, a beautiful walking and bicycling path encircling the entire belt. The primary function of this cultivation belt is to grow sufficient food for all the inhabitants of the city.

When looking at the water channels consider for a moment the wisdom of our ancestors in their choice to developed their living systems around a water source. Here, the waterways provide water storage, harvesting, irrigation, and purification. On the water channels there are water harvesting atmospheric generators with

Figure 25. *Concept diagram depicting service systems with service priority (i.e., some services are prioritized) and service fulfillment (accountable degree of completion of service system demand).*



solar distillation units. These evaporative condensation systems are one means by which the city creates clean drinking water. And, at least one channel is always available for swimming. There may be other primary rings closer to the center where water management occurs.

4.1.8 A natural barrier

Just beyond the final waterway is a ring constructed as a geomorphic vegetation-barrier. It is designed to prevent ecological disruption to the inner city and purify environmental run-off from the next belt outward. The vegetation selected for this natural barrier will have a second purpose, it will be used for harvesting into food, textiles, and many other useful materials.

4.1.9 A circular farming system

In this configuration the outer perimeter ring is [in part] a “circular farm”, a holistically planned grazing system also known by the names circular symbiotic cultivation, regenerative agriculture, rotational grazing, and syntropy farming. It is a biomimicry process that mirrors what occurs in nature. Here, the “farming” follows natural ecological cycles. This circular area is primarily a combination of pasture and orchard land that we move different animals through in a particular order to mimic natural cycles, which builds our soil base and provides food.

In this area there is grass between trees, and often, when left unchecked, the grass will grow up and choke out the tress (same with shrubs). Early 21st century society generally prevents this consequence by using a lawn mower. But, nature provides an alternative. Imagine running a number of different organisms around this circular ringed area. We send cattle through the orchard and let them mow down all the grass. And, as they go the cattle fertilize the tress. They deposit their waste, and then, trample it into the ground to create fertile, carbon rich soil. A few days after the cattle, we send the goats, who eat the shrubbery that the cattle wouldn’t necessarily eat. The goats also climb up and prune the bottom 6 feet of the trees. They also fertilize. Pigs are run through as left-over waste consumers. Then we send through the chickens in a mobile chicken coup. The chickens also fertilize the soil and eat all the bugs that hatch from the manure of the first two ruminants that went through. Chickens come in after the pigs have dug up big clumps of grass. They “cleaning out” the area and fertilize with their high nitrogen manure. So, at the least, we intentionally run 4 different animal species through this area, and as a result, we get multiple cultivations, we build up our soil base, and we have the opportunity to play a role in the well-being of other symbiotic species, while giving ourselves a picturesque environment to enjoy in a variety of fashions.

Among the circular farm, this ring may also be used for recreational activities such as biking, golfing, hiking and riding. Areas herein may be set aside for renewable, clean sources of energy, such as wind, solar, heat concentrating systems, geothermal, and others. There may also be large activity domes positioned around this ring if that is what the population of a particular city desires. Further, there could be lower-rise apartment type structures close to the outer edge for people who prefer apartments, but would like a more outdoors-type of living, close to where the city returns to wild nature. And finally, this outer perimeter could be considered another natural barrier, designed to prevent ecological disruption to the inner city.

4.1.10 Return to nature with care

Beyond the outer belt we allow the environment to return to nature, while still caretaking our total habitat. When a city reaches its planned size, we stop, and let everything go back to nature between this and the next city. There is no urban sprawl; mostly, we let everything return to nature between cities -- we let the environment return to its natural homeodynamic equilibrium. Out in nature we can wild food forage and re-learn the skills or our ancestors. Here, we ask ourselves, “What is it like to be just another animal in the wild?”

4.1.11 Wildlife preservations and corridors

Wildlife habitats, preservations and corridors, facilitate the restoration and preservation of natural ecologies, and provide many other useful functions, such as nature connection and education. A wildlife corridor, habitat corridor, or green corridor is an area of habitat connecting wildlife populations separated by human activities or structures. Simply, wildlife preservations are wild areas (which may still be caretaken by humans), where wildlife flourish and migrate. Wildlife corridors are purpose-built pathways that provide wildlife with the ability to travel safely from one separated habitat to another. Between cities in community there are many interconnecting wildlife preservations and corridors. Wild animals need to move to complete their life cycles.

4.1.12 Transportation

In concern to transportation, these cities generally contain two to four primary transportation gateways (i.e., entrances and exits). Few transportation gateways are needed for the city because of its efficient design. Transportation within the city and between cities is shared between autonomous transveyors, specialized electric motor vehicles, self-powered vehicles (e.g., bicycle), and mass rapid transporters (MRTs) – all in the form of emissions-free transport. The design of these cities removes the need for each individual (or family) to have a personal automobile. Of course, mostly, these cities are designed for walking. Some cities, however, are large enough to necessitate transveyors and/or an MRT system within their limits.

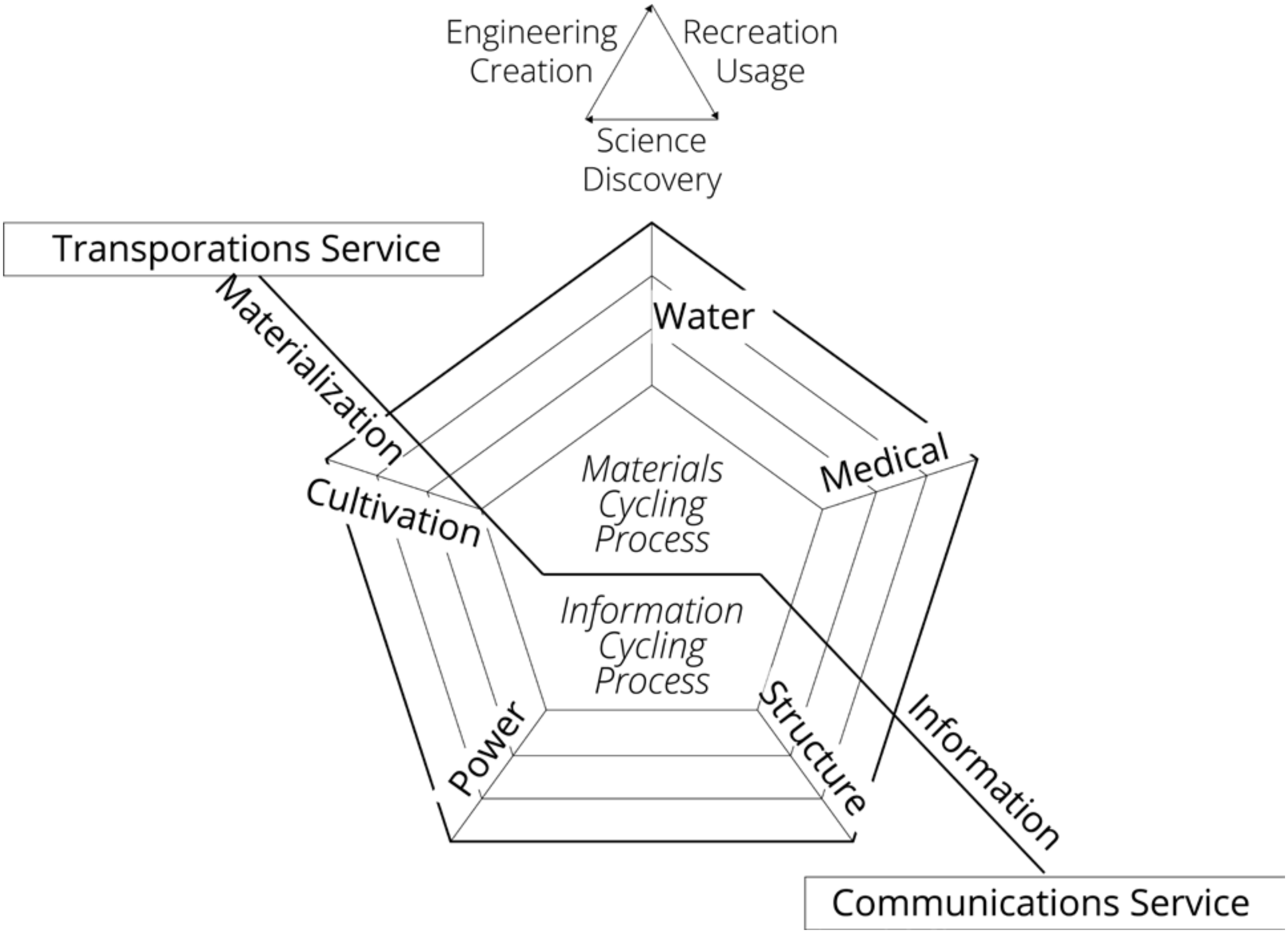
NOTE: *With a population of over 7 billion people* *on the planet it is essential for us to merge our knowledge of nature with a fulfillment-orientation that can guide the things we do and the cities we create.*

5 Biophilic design

Biophilic design is the practice of connecting people and nature within our built environments and communities. The promising new field of biophilia suggests that human beings have evolved with certain basic aesthetic and physiological needs: the presence of vegetation, water, sunlight, animals, and also the geometric relationships that have accompanied our evolutionary experiences with these structures. By tapping into this rich vocabulary of biophilic design elements, we can have an extremely rich variety of design possibilities — a rich range of artistic expression — while still meeting the needs of human beings. And within the same life-affirming process, we can meet the ecological needs of the environment too.

True, people have enormous varieties of experiences and tastes — and it's wonderful that they do — but these phenomena are generated by a common set of structural processes that are identifiable and shareable. Some experiences are unquestionably damaging to health and wellbeing, in the same way that, say, the structure of car exhaust molecules is damaging to health and wellbeing.

Figure 26. *Integration of life support and technological support into a model that produces the likelihood of societal structures of the informational and spatial order that sustain, and may even optimize, human fulfillment under dynamic and changing environmental conditions.*



It does no good to say our narrative about car exhaust is such and such, we want people to experience it and be provoked by it — that will not change the fact that we are making people unwell.

Doctors have learned that certain aspects of the patient environment promote well-being, and they now use this "evidence-based design" to improve the quality of life of their patients. In the same way, adaptive, human-scale architecture and urbanism rely upon discoverable rules of design. We proposed the existence of such rules while at the same time conjecturing that a non-adaptive aesthetic is easily reached from the adaptive design rules by simply reversing them. That is, since guidelines for designing adaptive, contextual environments are known instinctively, do the opposite to generate a form that strikes an observer by its visual novelty and lack of context.

> **INSIGHT:** *Awareness of a timeless language is present in people, but they learn to suppress it.*

Nature sees everything as a complex and continuous interaction where information is not separate from matter. Information has materiality, which has properties.'Digital materialization' refers to a two way conversion between matter and information. A system with the following four characteristics:

1. Symbolic - it has to be similar to the way we deal with other exact systems, like mathematics, or indeed, is mathematics itself.
2. Volumetric - it can't just be defining a 2.5D (a set of surfaces arranged in 3D space) it has to define at least 3D space, if not 4D.
3. Constructive - it needs to be modular; constructors must be able to work in chunks (e.g., like a Legos construction).
4. Continuous - it has to have continuous/infinite surface. can keep zooming in, you can keep going down to any resolution you want, you aren't limited.
5. Exact[ness] - the system has to have exact inputs and exact outputs.

6 Well-being design

> *A.k.a., Design for human well-being and neuroscientific concern.*

In the design of cities it is essential to use enhanced knowledge of the human experience and applied science as a basis for decisioning. It is important to design cities, and particularly, architecture therein, in a manner that accounts for the science around human well-being. For example, hospital designs are crucial to a patient's healing process. (Khuller, 2017) Only with a proper understanding of physiological and psychological factors, and a familiarity with available technologies, can decisions about habitat design be made for proper effect. City design in general, and architectural design in particular, can shape humans and their behaviors in ways that they don't realize, and yet, are highly predictable. Certainly, there are predictable emotional connections between humans and the architectural forms they build and surround themselves with. Architecture can get in the way and block, or alternatively, facilitate, individuals experiencing well-being from an environment.

> **INSIGHT:** *We shape our cities and later our cities shape us.*

The perception of an environmental space is heavily influenced by individuals' different past experience and memories, which can result in a difference in perception and experience. However, research into integrated neuroscience and the built environment can reduce the variety of these perceived perceptions by ensuring that designs are tailored to the needs of human beings. Hence, to ensure that an environment facilitates well-being for its users, designs must account for human needs as well as their personal preferences. A lack of detail in specifying the needs and characteristics of a user population will likely lead to misalignment of city design and users' experience. To minimise this difference in perception, the relationship between the task and environment must be defined as specifically as possible. The science of human requirements as well as neuroscience provides the scientific basis for more informed design decisions.

> *"The bad formation of towns influence the bad formation of minds." (Pemberton, 1854)*

7 Aesthetic design

INSIGHT: *There are places and environments that are just going to depress your heart rate variability.*

The human eye "likes things" in certain positions; it finds some positioning and proportioning more pleasing. Hence, community environments are often built in the proportion(s) of true beauty. Community developers often seek to create a sense of harmony and alignment with the pattered expression of nature in all space.

How the body relates to a space can be studied independently of what is going on in the mind (e.g., ergonomics), but how the mind engages space has to include the body and the brain of the individual. At the level of core, or basic, consciousness, humans are consciously and unconsciously registering the environmental variables' effects on their nervous system -- heat, light, noise, smells, tactile sensations, and a perception of movement and spatial orientation arising from stimuli within the body itself. All of these sensations are silently registering in the viscera as well as the somatosensory cortex via signals of which individuals are often not aware. At the level of extended consciousness, individuals are simultaneously experiencing space as assembled by their sensory system and combining this experience with memories of places similar to the one they are in. Individuals' minds are sorting through all of this to let them know they are dealing with a "reality". Part of the brain's internal environment is generated by a ceaseless pressure to seek out new stimuli. This is why humans are sometimes called "infovores", a term coined by neuroscientists Irving Biederman and Edward Vessel to mean a person who desires and seeks out information gathering. This hunger for information is one of the fundamental properties of the brain, and it is reflected in human individuals' most basic reactions (Biederman, 2006).

By understanding the biological basis for stress, we understand the potential for induced illness within a cognitive environment, as well as how to induce wellness. By understanding how lighting, acoustics, thermal conditions, and windows affect cognitive activity, we will have evidence for enriching the environment.

NOTE: *In Japan there is a term for the rejuvenation provided by being in nature. Shinrin-yoku, also known as "forest bathing" is a simple practice for enhancing health through sensory immersion in forests and other naturally healing environments.*

Parks and other green spaces make people happier, and the proof is in their brain activity. The understanding that nature-based environments facilitate health is the reason that walking in nature or a park is recommended for rehab patients and athletes in recovery. Nature also, perhaps, facilitates resource appreciation. Certainly, survival training facilitates an appreciation of resources.

INSIGHT: *Our environment has a profound impact on the way we feel and perform. We can create through cooperation and intelligence a micro environment inside nature that is supportive of us and our evolution.*

Scholarly references

- Aspinall, P., Mavros, P., Coyne, R., Roe, J. (2015). *The urban brain: analysing outdoor physical activity with mobile EEG*. British Journal of Sports Medicine, 49(4), pp272-6. DOI:10.1136/bjsports-2012-091877 [ncbi.nlm.nih.gov]
- Babar, M. and Arif, F. (2017). *Smart urban planning using big data analytics to contend with the interoperability in internet of things*. Future Generation Computer Systems, 77:65–76.
- Batten, D.F., (1995). *Network cities: Creative Urban Agglomerations for the 21st Century*. Sage Journals. DOI:10.1080/00420989550013103
- Batty, M., Cheshire, J. (2011). *Cities as flows, cities of flows*. Environment and Planning B: Planning and Design 2011, volume 38, pages 195-196. DOI: 10.1068/b3802ed [people.iup.edu]
- Bermudez, J., Krizaj, D., Lipschitz, D.L., et al. (2017). *Externally-induced meditative states: an exploratory fMRI study of architects' responses to contemplative architecture*. Frontiers of Architecture Research, 6(2), pp123-136. DOI: 10.1016/j.foar.2017.02.002 [sciencedirect.com]
- Ben-Joseph, E., Gordon, D., (2000). *Hexagonal Planning in Theory and Practice*. Journal of Urban Design, 5(3), pp237-265. [web.mit.edu]
- Biederman, I., Vessel, E., (2006). *Perceptual pleasure and the brain: A novel theory explains why the brain craves information and seeks it through the senses*. American Scientist. [cvcl.mit.edu]
- Cats, O., Vermeulen, A. (2019). *Modelling Growth Principles of Metropolitan Public Transport Networks*. Department of Transport & Planning, Delft University of Technology. [transp-or.epfl.ch]
- Chen, H., Gu, W., Cassidy, M.J., Daganzo, C.F. (2015). *Optimal transit service atop ring-radial and grid street networks: A continuum approximation design method and comparisons*. Transportation Research Part B: Methodological, 81, 755–774. doi:10.1016/j.trb.2015.06.012
- Chen, Y., Nakazawa, J., Yonezawa, T., Kawsaki, T., and Tokuda, H. (2016). *Cruisers: A public automotive sensing platform for smart cities. In Proceedings - International Conference on Distributed Computing Systems*. Volume 2016-August, pp767–768.
- Costa, P. Grey Box City: Building cybernetic urban systems for smarter simulations. Data - SMART CITIES - Volume 1 - eCAADe 37 / SIGraDi 23. [papers.cumincad.org]
- Grammenos, F., Tasker-Brown, J. (2002). Residential Street Pattern Design. Socio-economic Series, 75. [irbnet.de] [web.archive.org]
- Hopman, R., Scott, E., Spencer, C., Weissinger, K., Strayer, D. (2017). *Measuring Cognition in Nature - Neural Effects from Prolonged Exposure to Nature*.

[researchgate.net]
- Kallinikos, J. (2007). *The consequences of information*. Edward Elgar Publishing, Cheltenham.
- Kallinikos, J. (2011). *Governing through technology: information artefacts and social practice*. Palgrave Macmillan, Basingstoke.
- Kuzina, A. (2019). Conception of the operational information model of smart city control system. E3S Web of Conferences 97, 01024. DOI: 10.1051/e3sconf/20199701024 [e3s-conferences.org]
- Marshall, S. (2005). *Urban Pattern Specification*. Institute of Community Studies, London. [citeseerx.ist.psu.edu]
- Marvin, S., Luque-Ayala, A. (2017). *Urban Operating Systems: Diagramming the City*. International Journal Of Urban And Regional Research. DOI:10.1111/1468-2427.12479 [onlinelibrary.wiley.com]
- Mouhoubi, N., Boudemagh, S.S. (2015). The "Project" Approach in Urban: A Response to Uncertainty. World Academy of Science, Engineering and Technology International Journal of Humanities and Social Sciences, 9(4). [publications.waset.org]
- Ni, P., Kamiya, M., Ding, R. (2017). *Cities Network Along the Silk Road: The Global Urban Competitiveness Report 2017*. Springer.
- Oppezzo, M., Schwartz, D.L. (2014). *Give Your Ideas Some Legs: The Positive Effect of Walking on Creative Thinking*. Journal of Experimental Psychology: Learning, Memory, and Cognition, 40(4), pp 1142–1152. DOI:10.1037/a0036577 [apa.org]
- Pemberton, R. (1854). *The Happy Colony*. London. From: Rowe, C. (1976). The Mathematics of the Ideal Villa and Other Essays. The MIT Press, Cambridge, Massachusetts and London, England. p81. ISBN 0-262-18077-4 [flickr.com]
- Ramaprasad, A., Sánchez-Ortiz, A., & Syn, T. (2017). *A Unified Definition of a Smart City*. Electronic Government, 13–24. doi:10.1007/978-3-319-64677-0_2
- Ramaprasad, A., Sánchez-Ortiz, A., & Syn, T. (2017). *A Ontological Review of Smart City Research*. Twenty-third Americas Conference on Information Systems, Boston. [researchgate.net]
- Ronkko, E., Herneoja, A., Oikarinen, E. (2018). *Cybernetics and the 4D Smart City: Smartness as Awareness*. Challenges, 9(1). DOI: 10.3390/challe9010021 [mdpi.com]
- Santana, E.F.Z., Chaves, A.P., Gerosa, M.A., Kon, F., Milojicic, D.S. (2017). *Software Platforms for Smart Cities: Concepts, Requirements, Challenges, and a Unified Reference Architecture*. arXiv:1609.08089 [arxiv.org]
- Stepandic, J., Wognum, N., Verhagen, N.J.C. (Eds.) (2019). *Systems engineering in research and industrial practice*. Springer. p236.
- Stepanek, P., Mouzhi, G. (2019). *Validation and Extension of the Smart City Ontology*. Proceedings of the 20th International Conference on Enterprise Information Systems (ICEIS 2018). DOI: 10.5220/0006818304060413 [scitepress.org]
- Townsend, A.M. (2000). *Life in the real-time city: mobile telephones and urban metabolism*. Journal of Urban Technology 7.2, 85–104.
- Townsend, A.M. (2015). *Cities of data: examining the new urban science*. Public Culture 27.2 76, 201–12.
- Trappey, A.J.C., Trappey, C.V., Govindarajan, U.H., Sun, J.J. Chuang, A.C. (2016). *A Review of Technology Standards and Patent Portfolios for Enabling Cyber-Physical Systems (CPS)* in Advanced Manufacturing. IEEE Access (Volume: 4). pp7356-7382. DOI: 10.1109/ACCESS.2016.2619360. [ieeexplore.ieee.org] [docplayer.net]
- Uribe-Perez, N. and Pous, C. (2017). *A novel communication system approach for a smart city based on the human nervous system*. Future Generation Computer Systems, 76:314–328.
- Voutsina, K., J. Kallinikos and C. Sorensen (2007). *Codification and transferability of IT knowledge*. In Proceedings of the 15th European Conference on Information Systems, University of St. Gallen, St. Gallen

Book references

- Alter, A. (2014). *Drunk Tank Pink: And Other Unexpected Forces That Shape How We Think, Feel, and Behave*. Penguin Books.
- Amstutz, A.E. (1968). *City management––a problem in systems analysis*. Sloan School of Management, MIT, Cambridge, MA.
- Batty, M. (2013). *The new science of cities*. MIT Press, Cambridge, MA [complexcity.info, earlier article]
- Curl, J.S. (2019). *Making Dystopia*. Oxford University Press
- Clifford, M.A. (2018). *Your Guide to Forest Bathing: Experience the Healing Power of Nature*. Red Wheel. [shinrin-yoku.org]
- Easterling, K. (2014). *Extrastatecraft: the power of infrastructure space*. Verso, London.
- Espino, N.A. (2017). *Building the Inclusive City*. Routledge.
- Forrester, J.D. (1961). *Industrial dynamics*. Pegasus Communications, Waltham, MA.
- Forrester, J.D. (1969). *Urban dynamics*. MIT Press, Cambridge, MA
- Fresco, J., Meadows, R. (2007). *Designing the future*. Osmora Publishing. [files.thevenusproject.com]
- Glanville, R. (2007). *Try again. Fail again. Fail better: The cybernetics in design and the design in cybernetics*. Kybernetes, 36, 1173–1206. [asc-cybernetics.org]
- Goodall, B. (1987). *The Penguin Dictionary of Human Geography*. London: Penguin.
- Howard, E. (1898). *Garden Cities of To-Morrow*. Swan Sonnenschein & Co. [en.wikisource.org]
- Lasker, G.E. (1981). *Systems approaches in computer science and mathematics, Proceedings of the International Congress on Applied Systems Research and Cybernetics*. Pergamon Press.
- Light, J.S. (2003). *From warfare to welfare: defense intellectuals and urban problems in cold war America*. JHU Press, Baltimore, MD
- Meier, R.L. (1962). *A communications theory of urban growth*. MIT Press, Cambridge, MA.
- Ross, A.W. (1957). A*n Introduction to Cybernetics. In Principia Cybernetica Web (Principia Cybernetica, Brussels)*. Chapman & Hall Ltd. London, UK. [pespmc1.vub.ac.be]
- Webber, M. (1964). *Explorations into urban structure*.

University of Pennsylvania Press, Philadelphia
- Wiener, N. (1948). *Cybernetics: Or Control and Communication in the Animal and the Machine*. Wiley & Sons: New York, NY.

Online references

- Batty, M. *A science of cities.* Accessed: January 21, 2020. [complexcity.info]
- *Central place theory.* (2019). Wikipedia. [en.wikipedia.org]
- *Circular cities.* The Venus Project. Accessed: January 18, 2020. [thevenusproject.com]
- Delen. (2014). *The Quadralectic Theory*. Quadralectic Architecture. [quadralectics.wordpress.com]
- Delen. (2016). *The circular/radial model*. Quadralectic Architecture. [quadralectics.wordpress.com]
- Ellis, C. *History Of Cities And City Planning.* Accessed: January 17, 2020. [art.net]
- *FAQ*. The Venus Project. Accessed: January 18, 2020. [thevenusproject.com]
- Hakan. *Radial Grid*. Monovektor. Accessed: January 18, 2020. [monovektor.com]
- Khullar, Dhruv. (2017) *Bad Hospital Design Is Making Us Sicker*. The New York Times. [nytimes.com]
- Levinson, D. *Grids Are for Squares: 3 Reasons to Consider Alternatives for City Design*. Smart Cities Dive. Accessed: January 20, 2020. [smartcitiesdive.com]
- Notaro, A. (2005). *Imagining the Cybernetic City: The Venus Project. Nebula*. [cdn.atria.nl]
- Pumain, D. (2004). *Central places theory*. Hypergeo. [hypergeo.eu]
- *Quotes from Robert Park - Ernest Burgess Roderick McKenzie and Louis Wirth: Concepts for Human Ecology*. Andrew Roberts. Accessed: January 20, 2020. [studymore.org.uk]
- *Smart city.* (2020). Wikipedia. [wikipedia.org]
- *Systems of cities*. (2009). The World Bank: The International Bank for Reconstruction and Development. [siteresources.worldbank.org]
- *The circle*. (2011). AMSI. [amsi.org.au]
- *The Origin of Cities – Part 1*. (2016). the HipCrime Vocab. [hipcrimevocab.com]
- *The Origin of Cities – Part 2*. (2016). the HipCrime Vocab. [hipcrimevocab.com]
- *The Origin of Cities – Part 3*. (2016). the HipCrime Vocab. [hipcrimevocab.com]
- *The Origin of Cities – Part 4*. (2017). the HipCrime Vocab. [hipcrimevocab.com]
- *The Real Reason Jaywalking Is A Crime (Adam Ruins Everything)*. (2015). CollegeHumor. [youtube.be]

TABLES

Table 1. **City > Ontology**: *Smart city ontology within a community-type society.*

Smart								City		
Structure		**Functions**		**Focus**		**Semiotics**		**Stakeholders**		**Outcomes**
Information Technology		Sense		Life		Data		Users		Values (e.g., sustainability, resilience, etc.)
Projects		Monitor		Technological		Information		Teams		Quality-of-life / Well-being
Teams		Process		Exploration		Knowledge				Fulfillment
Processes	[to]	Translate	+	Resources	+		[by/from/to]		[for]	Flourishing
Procedures		Communicate		Access						Flow
				Social						
				Decision						
				Lifestyle						
				Material						

Land Accounting System

Travis Grant,

Affiliation contacts: *trvsgrant@gmail.com*

Version Accepted: 8 July 2022

Acceptance Event: *Project coordinator acceptance*

Last Working Integration Point: *Project coordinator integration*

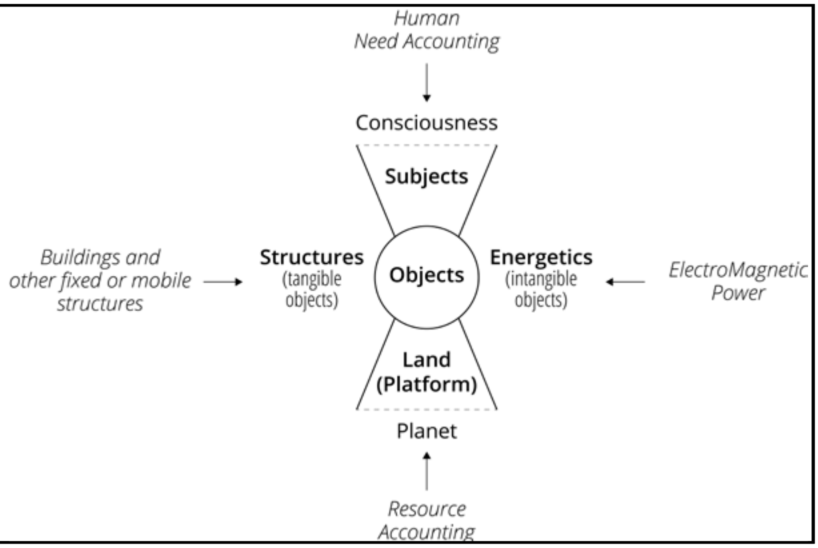
Keywords: land, land accounting, land assessment, geo accounting, site analysis, site survey

Abstract

All earth-based platforms must account for land. When engineering anything on land or ocean, the environment must be accounted for. Land is one necessary element for which to account. Land is accounted for through a land/site survey. When in use, land may be zoned and accounted for via the service/function upon its geo-coordinated position. In the market, land is considered property. In the State, land is considered jurisdiction.

Graphical Abstract

Figure 27. *Depiction of the account of material objects composed of four primary categories (structures, subjects, energetics, and land), of which land is a fundamental component. It is upon land (or, a "landed platform") that a set of useful services may be sustained.*



1 Introduction

Site analysis is an surveying and analytical process that gathers information from an environment where probable operation is to occur. Primarily, it involves the collection of data from various sources about a given spatial area where placement may occur. Data may be collected from all primary mediums in the placement area (i.e., land, liquid, and atmosphere). Site assessment is necessary in every design processes where placement in space is a consideration. It involves the gathering of data from a site for use in site selection and engineered construction.

Terminology includes, but is not limited to:

- Topography is a detailed map of the surface features of land [contours]. Topology is the study of place, from topo-, combination form of Greek topos "place" + -logy "study of".
- Site analysis
- Natural systems
- Human systems

PRIMARY: *For anything which is to be built, its design must account for its placement.*

In concern to the placement of buildings and other technologies on a specific area of land, then a site inquiry assesses the geomorphology and climate of the given environment [in the context of that which is to be selected or built].

For example, you would want to know whether the placement of a garden is on top of a former dumping ground. Or, you would want to know the surface shape upon which an object is to be placed -- is the surface round or flat, and how smooth?

A site analyses can provide data to analyse the difference (compare and contrast) between possible placement site locations.

A site survey provides information that may be useful in decisions involving:

- Site selection;
- The design of the object to be placed; and
- The re-design of the spatial area into which the object is to be placed.

The typical phases/generic steps in site analysis are program investigation, site investigation and analysis, site evaluation, and report development.

1. **Program investigation:** The building program is investigated with respect to the selected or optional building footprints; area required for parking, circulation, open space, and other program elements; and any special constraints or requirements such as security, easements, preserving natural habitat, wetlands, and the like.
2. **Site inventory and analysis:** The physical, cultural, and regulatory characteristics of the site are initially explored. The site evaluation checklist identifies factors that may be considered. Some of these factors can be assessed by collecting and analyzing information; others are best addressed by walking the site and traversing its environs. A preliminary assessment of whether a location and site have the potential to accommodate the building program is made. Priority issues—those (such as environmental contamination) that may preempt further investigation—are identified. A site analysis plan is developed. When this has been approved by the client, consultants may be hired to further explore issues that require analysis beyond the capabilities of the core project team.
3. **Site evaluation:** At this point, thorough assessments are conducted when necessary to develop the site analysis plan. These may include physical testing of aspects of the site, its improvements, and adjoining properties.
4. **Report development:** The site analysis report normally includes property maps, geotechnical maps and findings, site analysis recommendations, and a clear statement of the impact of the findings and recommendations on the proposed building program.

NOTE: *Regulatory approvals normally required during or immediately following the site analysis phase include zoning, environmental impact, and utilities & transportation.*

1.1.1 Geographical information system

Geographic information system (GIS) refers to the process collecting and mapping data about a spatial-temporal location. A GIS process records spatio-temporal (space-time) location as the index variable for all information.

In other words, just as a relational database containing text or numbers can relate many different tables using common index variables, GIS can relate otherwise unrelated information by using location and time as the index variable. The contextualizing factor is the location and/or extent in space-time. Any variable that can be located spatially, and increasingly also temporally, can be referenced using a GIS.

Locations or extents in space–time may be recorded as dates/times of occurrence, and x, y, and z coordinates representing, longitude, latitude, and elevation, respectively. Earth-based spatial–temporal location and extent references should, ideally, be relatable to one another and ultimately to a "real" physical location or extent.

Some common GIS data about any given location on

Earth might include topology with contour lines and elevations, soil and land mass composition, land use, wildlife, and even political districts. Any technology that can sense the real world can be used to collect GIS data. Some of the most common technologies referred to in the discussion of a GIS are the global positioning system, atomic clocks, remote sensing and imaging systems. Some commonly included models in a GIS are hydrological modeling, cartographic modeling.

2 Site survey and land assessment

A.k.a., Site analysis, land survey, land survey assessment, land assessment, land survey report, bio-geographic assessment, bio-region assessment, geographical region assessment.

This is a checklist of the factors that may be involved in the gathering of data about a "site". A "site" is a spatial location of an area where something which is being designed and constructed may likely, or will, be placed). In our controlled habitat information is continuously collected, because the designed construction of our habitat service system is emergent.

NOTE: *The site survey assessment as it presently exists here is oriented toward market-State conditions and does not represent a clean site survey as would be done in an environment without the market-State.*

Planning should, if possible, be undertaken before the land is acquired as this will enable the viability to be assessed before substantial investment has been made.

A site analysis (a.k.a., land survey assessment) may include the following analyses:

1. Site analysis (site survey)
2. Land survey (evaluation of land)
3. Cope survey (post occupancy evaluation)
4. Perimeter survey
5. Climate analysis
6. Geological analysis
7. Geotechnical analysis (geotechnical survey)
8. Ground investigation
9. Soils analysis (soil survey)
10. Water analysis
11. Surroundings analysis (e.g., natural artifacts, neighbours, etc.)
12. Demographic analysis
13. Psychological implications analysis (e.g., beauty, light, etc.)
14. Jurisdictional/political analysis

NOTE: *A complete site/land analysis includes jurisdictional/political analyses, because all land in the early 21st century is principally owned by State jurisdictions.*

The following should, if possible, be undertaken before the land is acquired (i.e., purchase), as this will enable the viability to be assessed before substantial investment has been made:

1. Geological assessment
2. Soil and water assessment
3. Keyline (water) site planning
4. Regulatory assessment

2.1 Sale factors

Commercial and State factors that directly relate to land acquisition.

1. **Property specific data.**

    A. Link of listing:

    B. Address of listing:

    C. Contact name:

    D. Municipality:

    E. Regulatory bodies:

    F. Coordinates (with property line):

    G. Size of land (with property line):

    H. Shape/dimensions of land (with property line):

    I. Total price:

    J. Type of land *(as percent rural, urban, etc)*:

    K. Many/other local lands for sale:

    L. Size of surrounding lots and approximate price ranges:

    M. Sale price of last sold property (or, properties) in the area:

    N. Size and currency price (price per area):

    O. Taxes on land when purchased:

    P. Taxes on house when built:

    Q. Yearly taxes totals breakdown:

2.2 Physical factors

Real-world material factors that influence the decision, and subsequent decisions.

2.2.1 Climate

2. **Prevailing winds.**

    A. Direction:

    B. Maximum, minimum, and average velocities:

    C. Special forces (e.g., tornadoes, hurricanes, floods, flash floods, landslides):

    D. Wind direction on land throughout the day:

    E. Wind direction on land throughout the year:

3. **Solar orientation.**

    A. Sun angles:

    B. Days of sunlight:

    C. Cloud cover:

    D. Shading of (or from) adjacent structures, natural features, vegetation (where are shadows in the land, and from what structures):

    E. Sun direction on land throughout the day:

    F. Sun direction on land throughout the year:

4. **Temperature.**

    A. Ranges of variation:

    B. Maximums and minimums:

5. **Humidity.**

    A. Ranges of variation:

    B. Maximums and minimums:

    C. Precipitation:

    D. Peak period totals:

    E. Annual and seasonal totals:

6. **Storms.**

    A. Types and severity:

    B. Direction:

2.2.2 Topographic factors

Topography is the arrangement of the natural and artificial physical features of an area. The topographic factors are also called indirect factors as they influence the growth and development of organisms by bringing variations in climatic factors.

2.2.2.1 Land topography

Land topography is a digital image of the three-dimensional structure of the Earth's surface.

7. **Topographic maps and aerial images.**
    A. Contours and spot evaluations
        1. A contour map provides information on the rise and fall, and flow of the land:
        2. An orthophoto map (aerial photomaps) provide increased contour detail and a view of landscape objects:
    B. Slopes; percentage, aspect, orientation:
    C. Escarpments:
    D. Erosion channels:
    E. Extent, location, and general configuration of rocks, ledges, outcrops, ridges, drainage lines, and other unique features:
    F. Visual characteristics:
    G. Potential problem areas during construction: situation, erosion, precipitation, etc.:
8. **Analysis of physical features, including major focal and vantage points and their relationship within, into, and out from the site.**
    A. Unique topography:
9. **Existing access and circulation.**
    A. Human locomotion:
    B. Human easement:
    C. Vehicle locomotion:
    D. Vehicle easement:
10. **Vegetation.**
    A. Type:
    B. Specific names:
    C. Locations on land:
11. **Existing water bodies.**
    A. Location, size, depth, direction of flow:
    B. Water quality (clean, polluted, anaerobic conditions, etc.):
    C. Flow and usability (seasonal, year-round):
    D. Wetlands and other water-based ecological features:
    E. Flood planes:
    F. Variations (expected water levels, tides, wave action):
    G. Coastal features:
12. **Drainage canals (rivers, streams, marshes, lakes, ponds, etc.).**
    A. Natural and built:
    B. Alignments and gradients:
    C. Patterns and direction:
13. **Existing waterway easements.**
    A. Surface:
    B. Subsurface:
14. **Surface drainage.**
    A. Patterns on and off the site (location of streams and washes):
    B. Hydrological features (e.g., swales, berms, etc.):
    C. Proximity to floodplains:
        1. Maximum flood levels:

2. Frequent flood areas:

D. Local watershed areas, amount of runoff collected, and location of outfalls:

E. Swampy and concave areas of land without positive drainage and other obstacles that may interrupt or obstruct natural surface drainage:

F. Potential areas for impoundments, detention/ retention ponds:

15. **Unique site features.**

A. List:

2.2.2.2 Geotechnical

Geotechnical is a branch of civil engineering that deals with the earth materials engineering behavior.

16. **Land formation.**

A. What primary geological events/processes influenced the land forms of the area:

17. **Basic surface soil (e.g., sand, clay, silt, rock, shale, gravel, loam, limestone, etc.).**

A. Type of soil:

B. Depth of soil:

18. **Rock and soil type (character/formation and origin).**

A. Geologic formation process and parent material:

B. Inclination:

C. Bearing capacity:

D. Interference with construction and cultivation:

19. **Minerals.**

A. What are the minerals on the land?

B. Where are the minerals/rocks on the land?

20. **Bedrock.**

A. Depth to bedrock:

B. Bedrock classification:

C. Interference with constructions and cultivation:

21. **Seismic conditions.**

A. Type:

22. **Environmental hazards.**

A. Type:

23. **Water table level.**

A. Meters:

2.2.2.3 Soil

Soil is the terrain surface material composed of minerals, living organisms, soil organic matter, gas, and water.

24. **Soil test to determine the composition of the soil.**

A. What is the mineral and organic composition of the soil?

25. **What is the rock base underneath the soil?**

A. Type:

26. **How far deep is the rock base underneath the landscape?**

A. Meters:

27. **What is compaction (PSI) of the soil?**

A. PSI:

28. **What is the water retention of the soil?**

A. Type

29. **What is the water retention of the landscape?**

A. Type

2.2.3 Location factors

Location factors refer to specific physical factors related to habitation in the environment.

2.2.3.1 Utilities and municipality

Utilities are basic services that provide for the basic functioning of life and technical support of the habitat.

30. **Potable water.**
    A. Source:
    B. Quality test:
31. **Electricity.**
    A. Source:
    B. Quality:
32. **Gas.**
    A. Source:
    B. Quality:
33. **Communications/data (Internet).**
    A. Source:
    B. Quality:
34. **Sanitary sewer service.**
    A. Source (where does sewage go?):
    B. Quality:
35. **Trash collection and disposal.**
    A. Collection type/quality:
    A. Collection frequency:
    B. Distance to landfill (where does garbage go?):
36. **Storm drainage (surface, subsurface).**
    A. Source:
    B. Quality:
37. **Fire protection.**
    A. Source:
    B. Quality:
38. **Police/security protection.**
    A. Source:
    B. Quality:
39. **Mail.**
    A. How do you get mail:
    B. Quality of service:

2.2.3.2 Immediate surroundings

Environmental and population factors in the immediate surrounding environment.

40. **Local structures.**
    A. Buildings:
    B. Cell towers:
    C. Airports:
    D. Flight paths (air traffic patterns):
    E. Satellite dishes:
    F. Etc:
41. **Commercial entities.**
    A. Business/shop types:
    B. Distance to businesses and shops:
42. **Commercial services.**
    A. Schools and churches:
    B. Shopping centers:
    C. Parks:
    D. Municipal services:
    E. Recreational facilities:

F. Banks:

G. Food services:

H. Health services:

I. Access to highways, public transportation:

43. **Industrial entities.**

A. Industry types:

B. Distance to industrial locations:

44. **Shading and solar access.**

A. From trees:

B. From buildings:

C. From mountains:

45. **Views and vistas.**

A. View of land:

B. View of mountain:

C. View of air:

D. View of water:

46. **Wilderness and national parks.**

A. What is the largest wilderness area in the region and how close is it:

47. **Who owns the land around the property?**

A. Name and contact details:

B. How much land around the property can be acquired as a buffer between the property and other property owners?

48. **What is being done with the land around the property?**

A. Type of usage:

B. Will the local land usage interfere with the habitat?

49. **Population and demographics of local people.**

A. Population size:

B. Age:

C. Education level:

D. Income level:

50. **Support of local people.**

A. Interests:

B. Socio-economic level:

C. Will to support:

2.2.3.3 Transportation and infrastructural services

Transportation and distance related to the land.

51. **Type of road to arrive.**

A. Type of driveway road:

B. Easement of driveway road (does the driveway pass through other people's property):

C. Distance to main road:

D. Type of main road:

52. **Distance to.**

A. Fire and police protection services:

B. Trash/refuse removal services:

C. Snow removal, including on-site storage:

D. Hospital (medical) services:

E. Small airport services:

F. Major airport services:

G. Major highway services:

H. Major railway and bus services:

53. **Transportation for construction and operation.**

A. How easy will it be to transport materials, tools, and personnel to the property?

B. What is the cost to transport materials, tools, and personnel to the property?

C. How far away from a major (or minor) road is the property?

D. How far away from a main airport is the property?

2.2.4 Ecological factors

Ecological factors are components of the environment that can influence the organisms directly or indirectly in natural (non-human) ways.

2.2.4.1 Bio-region

54. **Bio-region of the landscape.**

    A. What is the name of the bio-region?

    A. What plants are native to this landscape?

    B. What plants are common to this bio-region?

    C. What animals are native to this landscape?

    D. What predators (that could harm livestock) are native to this landscape?

    E. What animals are common to this bio-region?

55. **Ecology.**

    A. What are the largest risks to the ecology?

2.2.5 Pollution factors

Factors related to pollution in the local area and at greater distance that could impact the location.

2.2.5.1 Land

Pollution originating from land sources.

56. **Material pollution (from land-base).**

    A. Sources and types:

57. **Noise pollution (from land-base; e.g., streets, emergency services, etc.).**

    A. Sources and types:

2.2.5.2 Water

Pollution originating from water sources.

58. **Material pollution (from water-base).**

    A. Sources and types:

59. **Noise pollution (from water-base; e.g., boats, etc.).**

    A. Sources and types:

2.2.5.3 Atmosphere

Pollution originating from air sources.

60. **Material pollution (from atmospheric-base).**

    A. Sources and types:

61. **Noise pollution (from atmospheric-base; e.g., aircraft, etc.).**

    A. Sources and types:

2.2.5.4 **Odors**

62. **Odor pollution**

    A. From land:

    B. From water:

    C. From air:

2.3 Land use factors

Factors related to how the land was used previously.

2.3.5.1 Site history

63. **Buildable area.**

    A. Square meters:

64. **Existing buildings.**

    A. Type:

B. Location on site:

65. **Former site uses.**

A. Hazardous dumping:

B. Landfill:

C. Old foundations:

D. Archaeological grounds:

66. **History of existing structures.**

A. Historic worth:

B. Affiliations:

C. Outline:

D. Location:

E. Floor elevations:

F. Type:

G. Condition:

H. Use or service:

67. **Type of land ownership.**

A. Type:

68. **Function and pattern of land use: public domain, farm type, grazing, urbanized.**

A. Present:

B. Former:

69. **Adjacent (surrounding) land uses.**

A. Present:

B. Projected:

C. Probable effects on the development of this site:

2.4 Property factors

Factors related to property.

2.4.5.1 Property relations and ownerships

70. **Analysis of legal property.**

A. Limits of property:

B. Easement:

C. Rights of way:

D. Deeds:

2.5 Jurisdictional and regulatory factors

2.5.5.1 Jurisdictional financial factors

NOTE: *Usage and ownership of land in a governmental jurisdiction [essentially] always requires some yearly (or cyclical) tax (rental) payment to the government. Land taxation is a financial cost.*

71. **Government taxes.**

A. Purchase tax price:

B. Yearly tax price:

72. **State taxes.**

A. Purchase tax price:

B. Yearly tax price:

73. **Municipality taxes.**

A. Purchase tax price:

B. Yearly tax price:

74. **Other tax implications:**

A. Identify:

75. **Jurisdictional-legal costs.**

A. Purchase legal price:

B. Yearly legal price:

76. **Submittal fees.**

A. Identify:

77. **Total land cost.**

A. Total purchase price (purchase of land including all taxation by governmental and legal fees):

B. Total yearly price (yearly rental from the government and legal fees):

C. Inflation rate (expected rise in costs over the next *x* number of years):

2.5.5.1 *Bureaucracy factors*

A. Describe complexity of bureaucracy:

B. Describe relationship with politicians and bureaucrats:

2.5.5.2 *Submittal factors*

78. **Special submittals required for approval and/or hearings.**

A. Fees (financial costs):

B. Applications:

C. Drawings:

D. Color presentations:

E. Sample boards:

F. List of adjacent land owners:

G. Other:

2.5.5.3 *Municipality future plans*

79. **Current planning of the future municipality.**

A. Describe:

2.5.5.4 *Zoning codes (including: municipality, city, town, village, etc.)*

80. **Permitted uses.**

A. Type of site:

B. Type of adjacent:

A. What is permitted:

B. By variance:

C. By special use permits:

D. Accessory structures:

81. **Check zoning laws.**

A. Check deed about zoning laws, including for livestock:

B. Check county about zoning laws, including for livestock:

C. Check town for zoning laws, including for livestock:

D. Check local covenants, including for livestock:

82. **Building allowance.**

A. Is the building size allowed (including, maximum building coverage):

B. Is the building type allowed:

C. Is the building location allowed:

83. **Minimum site area requirements.**

A. List:

84. **Building height limits.**

A. Identify:

85. **Yard (setback) requirements.**

A. Identify:

86. **Lot coverage.**

A. Total area:

B. Floor area ration (FAR):

C. Percentage of coverage:

D. Open space requirements:

87. **Loading zone requirements.**

A. Identify:

88. **Parking layout restrictions.**

A. Identify:

89. **Off-street parking requirements.**

A. Identify:

90. **Landscaping requirements.**

A. Identify:

91. **Sign (signage) requirements .**

A. Identify:

92. **Zoning due diligence.**

A. Has zoning due diligence been completely done:

2.5.5.5 Covenants codes

93. **Is the property under any covenants?**

A. If yes, where are those covenants filed? Note that someone may only be able to determine if a covenants exists by going to the county courthouse (or other jurisdictional headquarters) and checking?

B. If yes, what do those covenants say about what is allowed and what is not allowed?

C. If yes, how often is the covenants renewed and what is required for its renewal?

NOTE: *It doesn't take a lot of effort for a group of upset and angry neighbours to write a petition and create some sort of law to get property owners kicked off their property or stop someone from living a particular lifestyle (e.g., such as having the animals removed).*

2.5.5.6 Other contracts

94. **Private contracts, conditions, and restrictions (CC&Rs) that are associated with the land should be checked:**

A. Identify

2.5.5.7 Subdivision, site plan review, and other local requirements and codes

95. **Lot requirements.**

A. Size:

B. Configuration:

C. Setbacks and coverage:

96. **Street requirements.**

A. Widths:

B. Geometry: grades, curves:

C. Curbs and curb cuts:

D. Road construction standards:

E. Placement of utilities:

F. Dead-end streets:

G. Intersection geometry:

H. Sidewalks:

I. Names:

97. **Drainage requirements.**

A. Removal of spring and surface water:

B. Stream courses:

C. Land subject to flooding:

D. Detention/retention ponds:

98. **Parks.**

A. Open space requirements:

B. Park and playground requirements:

C. Screening from adjacent uses:

2.5.5.8 Environmental regulations

99. **Water, sewer, recycling, solid waste disposal.**

    A. Location:

100. **Clean air requirements.**

    A. Identify:

101. **Soil conservation.**

    A. Identify:

102. **Protected areas, wetlands, floodplains, coastal zones, wild and scenic areas.**

    A. Identify:

103. **Fish and wildlife protection.**

    A. Identify:

104. **Protection of archaeological resources.**

    A. Identify:

2.5.5.9 Other codes and requirements

105. **Historic preservation and landmarks.**

    A. Identify:

106. **Architectural (design) controls.**

    A. Identify:

107. **Special district.**

    A. Identify:

108. **Miscellaneous (e.g., mobile homes, billboards, noise).**

    A. Identify:

109. **Site-related items in building codes.**

    A. Building separation:

    B. Parking and access for persons with disabilities:

    C. Service and emergency vehicle access and parking:

3 Land acquisition requirements

The following are requirements for land acquisition for a rural habitat service system:

1. **Price**

   A. Identify budget: 100,000USD (500,000R$) +tax,lawyer,upgrading,...

2. **Area**

   Note: The land space necessary for animals and plants will depend on soil fertility and previously cultivated or growing organisms.

   A. Identify area: 15Ha - 20Ha = 150,000m^2

   B. Identify relief: More or less flat, light contour lines.

   C. Identify pollution: Need to be away from harsh chemical agriculture and other significant sources of pollution.

   D. Identify geological: Rock placement should not interfere other architectural-engineering construction plan or with permacultural plan.

   E. Identify water: Must have a water source in the area.

3. **Price to area**

   A. Identify price/area: 28,000/Ha

4. **Construction estimation**

   A. Identify construction budget & cost: 1,000,000USD

5. **Infrastructures present**

   A. Types: YES

   B. Quality: GOOD

6. **Water**

   A. Location: YES

   B. Quality: GOOD

7. **Environmental quality**

   A. Identify: GOOD

8. **Landscape contour (land relief)**

   A. Identify: 20-30% relief

9. **Accessibility of land**

   A. Identify: 0-5km

10. **Neighborhood**

    A. Identify: GOOD

4 Land surveying for construction

A.k.a., Construction survey, land surveying and mapping.

The land requires a survey, wherein a master plan drawing is aligned onto the terrain wherein physical markers are placed on the land to designate areas. The surveying process involves staking out (with physical stakes and positional references) the location of planned structures (e.g., buildings, fences, etc.) and modifications (e.g., earthworks). These reference points and markers will then guide the construction. These markers are usually staked out according to a suitable coordinate system selected for the project.

1. Survey existing conditions of the future work site, including topography, existing buildings and infrastructure, and underground infrastructure whenever possible (for example, measuring invert elevations and diameters of sewers at manholes).
2. Stake out lot corners (perimeters), stake limit of work and stake location of construction trailer (clear of all excavation and construction).
3. Stake out reference points and markers that will guide the construction of new structures.
4. Verify the location of structures during construction.
5. Provide horizontal control on multiple floors.
6. Conduct an As-Built survey: a survey conducted at the end of the construction project to verify that the work accounted for ("authorized") was completed to the specifications set on plans.

Surveying equipment include, but may not be limited to:

1. Levels.
2. Theodolites - used for accurate measurement of angular deviation, horizontal, vertical and slope distances.
3. Electronic distance measurement (EDM).
4. Total stations.
5. GPS surveying.
6. Physical staking.
7. Rope connected stakes.
8. Laser scanning.
9. GIS computation and visualization.

There are three primary types of land surveys herein, including:

1. **Land surveying (a.k.a., land database survey)** - is used to identify the physical quantities and qualities of the land, including present resources and cultural conditions. 'Site survey and land assessment' (3.0, earlier section) form must be filled in completely to have filled in a complete land survey form. There are no changes made by the surveyor to the physical land. Instead, the land surveying process involves filling in a database of separate inquiries about the current, past, and future possible state of the land. A database survey is completed by a research and discovery effort into the land.
2. **Site planning survey (a.k.a., plot plan or survey)** - is a plan of the entire property, drawn to scale, that shows the location and dimensions of all property lines, any existing and proposed structures, and any proposed exterior work. A site planning survey combines the elements of boundary and topographic surveys for site planning, and may even include succession (in possible terms of plants, animals, and structures). This type of survey is used to plan the whole design and development of a site before construction begins. It may be submitted to government officials for approval. Site plans are frequently required by the State for acquisition to State required permits that allow [for] development (construction) operations. In most States, anytime a structure or use is added to a property (such as fence, shed, parking, addition, house, farm, etc.) an accurate site plan is required to determine if the project meets all State zoning code requirements (and other legal codes and standards). A site plan survey is a combination of a 'boundary survey' and 'topographic survey':
   A. **A topographic survey** - is used to establish elevations and relief. A topographic survey is a land or aerial survey that gathers data about the elevation of points on a piece of land and presents them as contour lines on a plot. A topographical survey shows a 3D depiction of land on a 2D product with contour interval lines. Contour lines are useful because visualizes the various elevations on a plot of land. Topographic surveys are used to inform construction, erosion and other environmental issues, zoning issues, etc. The topographic survey provides the first layer of the site planning documentation.
   B. **A boundary survey (a.k.a., market-based property line, designating individually enforceable State ownership) -** is used to locate the corners and boundary lines of a parcel of land. This is someone's land-ed territory; first, landed by a State-government and then landed by individual or corporate citizens of that authority. This type of survey involves both record and field research, including any measurements and computations needed to set the boundary lines in accordance with applicable State laws. A boundary survey may also involve locating easement lines and

encroachments. Once surveyed, the boundary line should be physically staked. This survey identifies the lot dimensions in the physical and in an architectural orthographic top 2D view. A single line, or set of single lines designates the bounded location(s) on the topological terrain map.

C. **Construction surveying (a.k.a., site plan specification documentation, site construction survey)** - is used to stake out structures and specified functional areas located on the property, including walls, buildings, roads, and utilities. Staking provides construction personnel with directions for executing the decisions shown on the development master plans (i.e., in the site planning survey). A construction survey may also involve both horizontal and vertical grading in addition to an as-Built survey.

5 Surveying organizations and standards

5.1 Surveying organizations

- **International Federation of Surveyors (FIG)** [fig.net] - a federation of national member associations associated with surveying. FIG covers the whole range of professional categories within the global surveying field, including: surveying, cadastre, valuation, mapping, geomatics, geodesy, hydrography, geospatial, geo-information and quantity surveyors and provides an international forum for discussion and development aiming to promote professional practice and standards.

TABLES

Table 2. Land Accounting: *Hierarchical classification of geomorphological features (time and space scales are approximate).*

Hierarchical Classification Of Geomorphological Features			
Typical units		Spatial scale km^2	Time Scale Years
Continents		10^7	10^8-10^9
Physiographic provinces, mountain ranges		10^6	10^8
Medium and small scale units, domes, volcanoes, troughs		10^2-10^4	10^7-10^8
Erosional/depositional units:			
	Large scale, large valleys, deltas, beaches	10-10^2	10^6
	Medium scale, floodplains, alluvial fans, cirques, moraines	10^{-1}-10	10^5-40^6
	Small scale, offshore bars, sand dunes, terraces	10^{-2}	10^4-10^5
Geomorphic process units:			
	Large scale, hillslopes, channel reaches, small drainage basins	10^{-4}	10^3
	Medium scale, slope facets, pools, riffles	10^{-6}	10^2
	Small scale, sand ripples, sand grains, striations	10^{-8}	

Resource Accounting System

Travis A. Grant,

Affiliation contacts: *trvsgrant@gmail.com*

Version Accepted: 8 July 2022

Acceptance Event: *Project coordinator acceptance*

Last Working Integration Point: *Project coordinator integration*

Keywords: resource, resource accounting, object accounting, resource survey

Abstract

All earth-based platforms must account for resources. When engineering anything, its object composition, and the composition of the environment where objects are distances from one another, must be accounted for. Resources are one necessary element for which to account when planning project and operationalizing a product. Resources are accounted for through a global resource survey. In the market, resources are property. Spatial resources (true resources) are objects (i.e., made of matter/shape). Informational "resources" (digital resources) are data (i.e., made of bits). Human "resources" (contributors) are individuals (i.e., made of consciousness). Consciousness uses spatial and informational resources in order to sustain its embodiment and to develop itself.

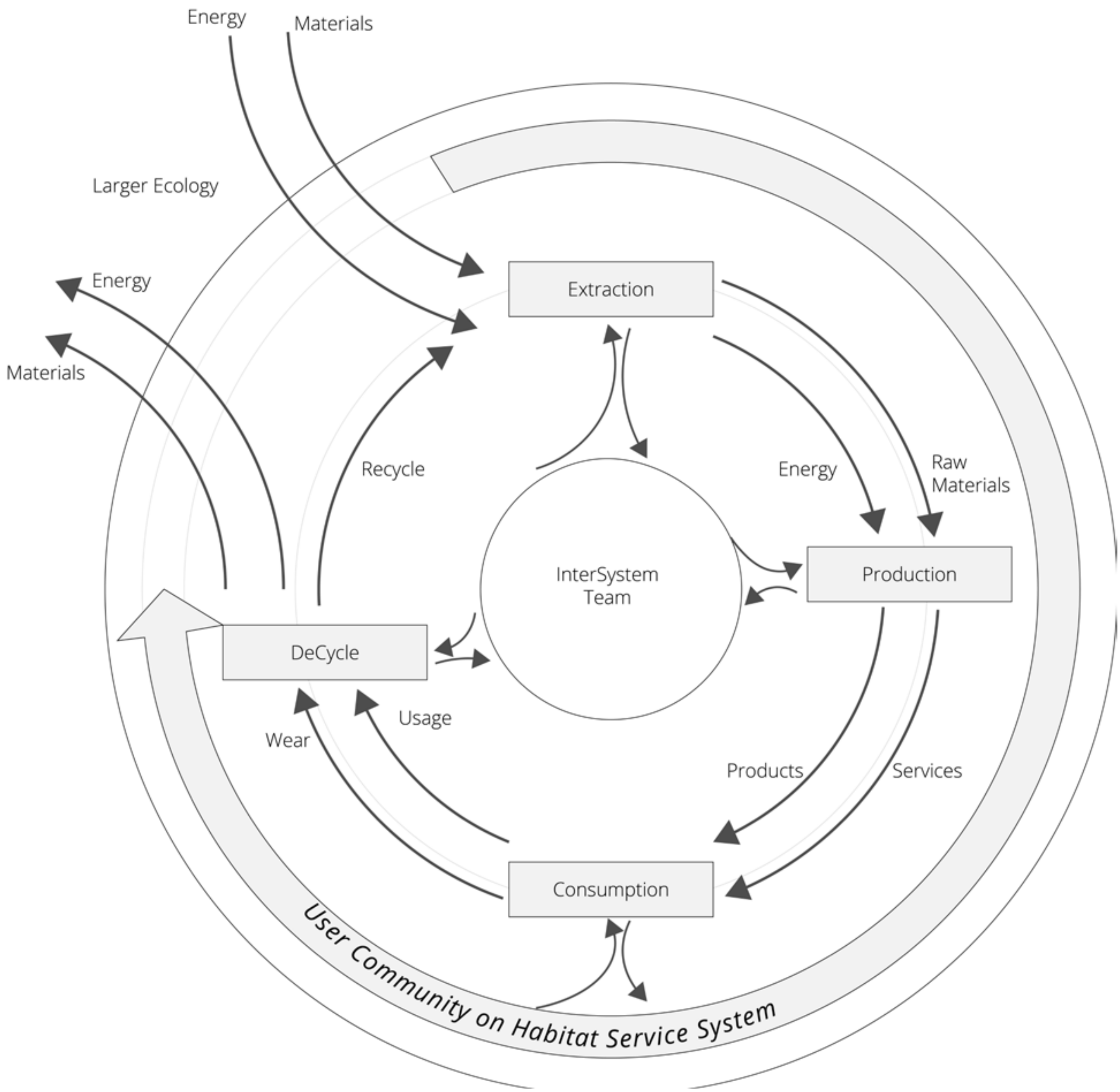
Graphical Abstract

Figure 28 on page 62

1 Resource surveying

A.k.a., Global resource survey.

Figure 28. *The engineering of a real-world material cycle of resources for human "consumption" through team contribution.*



Access Accounting System

Travis A. Grant,

Affiliation contacts: *trvsgrant@gmail.com*

Version Accepted: 8 July 2022

Acceptance Event: *Project coordinator acceptance*

Last Working Integration Point: *Project coordinator integration*

Keywords: access, access accounting, access surveying

Abstract

All societal-based platforms must account for access. When producing anything, access to that thing must be accounted. Access is necessary and two dimensional concept. Firstly, there is access to a team or working group through a contribution-based structure, and then, there is access to goods and service (without force of trade). Access can be accounted for many types of surveys including demand surveys, contribution surveys, etc. In the market, access is considered through the cost of a sale. In the State, access is acquired through authority. Humans require access to objects and information, which are composed into services. In a market, access is controlled by price, and the concept itself is mixed with "rights" (given by authority) and "property" (purchased in the market). In a community-type society, access refers to demands and other issues for service that are accessible to users. Ultimately, the goal is to have access to that which optimally meets user requirements (human needs) given that which is available at the time of access. In a community-type society, access centers and integrated transportation systems distribute products. Services are integrated, often modularly, into the infrastructure of the environment in order to optimize efficiency and produce a higher quality experience of access [to services] by a user. With sufficient technical knowledge and ability it is possible to apply automation technologies to increase the efficiency by which access occurs. Automation technologies can free individuals for access to opportunities they might otherwise not have had. Automation technologies can also make access to services, such as medical and informational more safe, reliable, and faster.

Graphical Abstract

Figure 29 on page 65

1 Habitat access centers

A.k.a., Access locations, libraries, repositories, etc.

A library of accessible items are available at access centers.

2 Automated storage and retrieval system

No content here yet *(sometimes shown and sometimes not; not yet complete, but category is known)*

3 Access location designations

There are three types of material access designation:

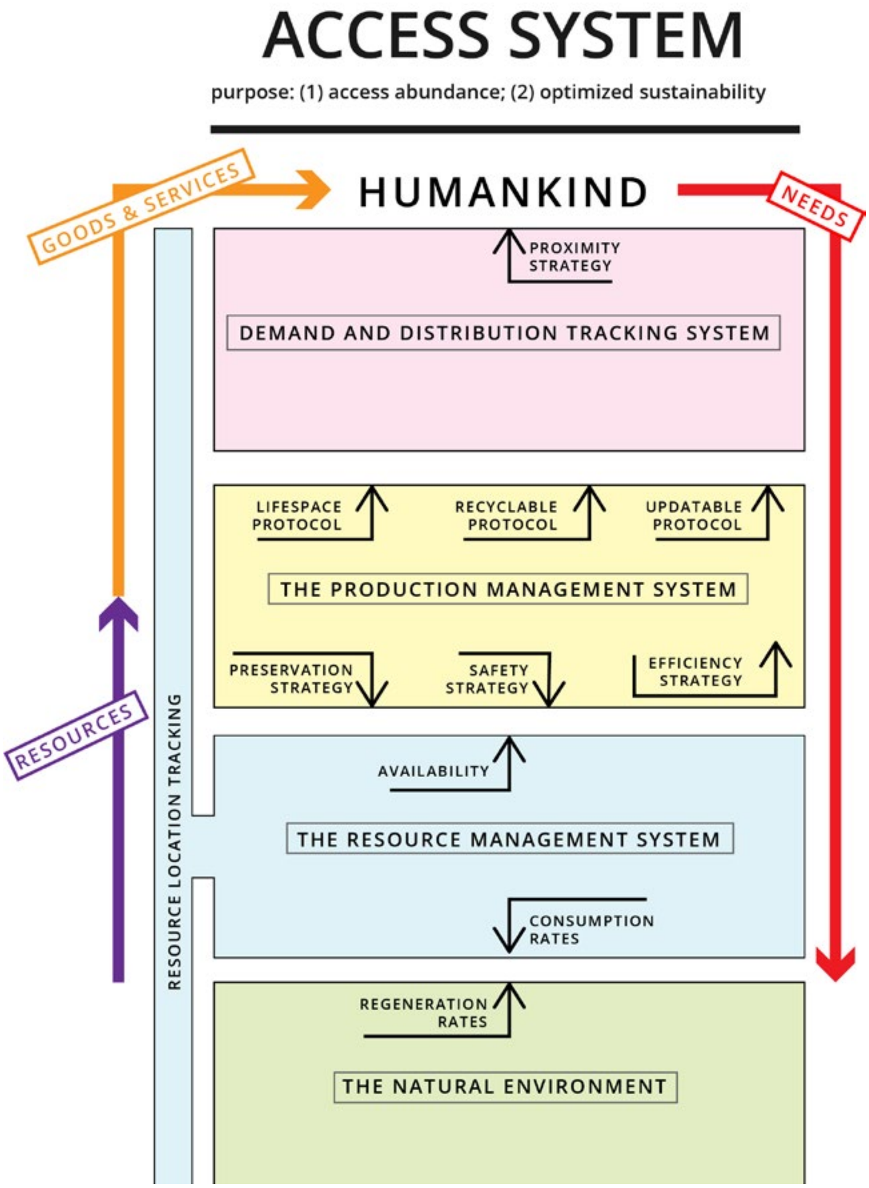
1. Personal access designations
2. Common access designations
3. Systems access designations

Location specific [visitation] attributes include, but are not limited to:

1. Frequency [of visit to location]
2. Duration [of visit to location]
3. Recency [of visit to location]

These elements should be accounted for in the design and selection of zones, circulars, and other material access locations.

Figure 29. *Resource tracking within an access system.*



Technology Accounting System

Travis A. Grant,

Affiliation contacts: *trvsgrant@gmail.com*

Version Accepted: 8 July 2022

Acceptance Event: *Project coordinator acceptance*

Last Working Integration Point: *Project coordinator integration*

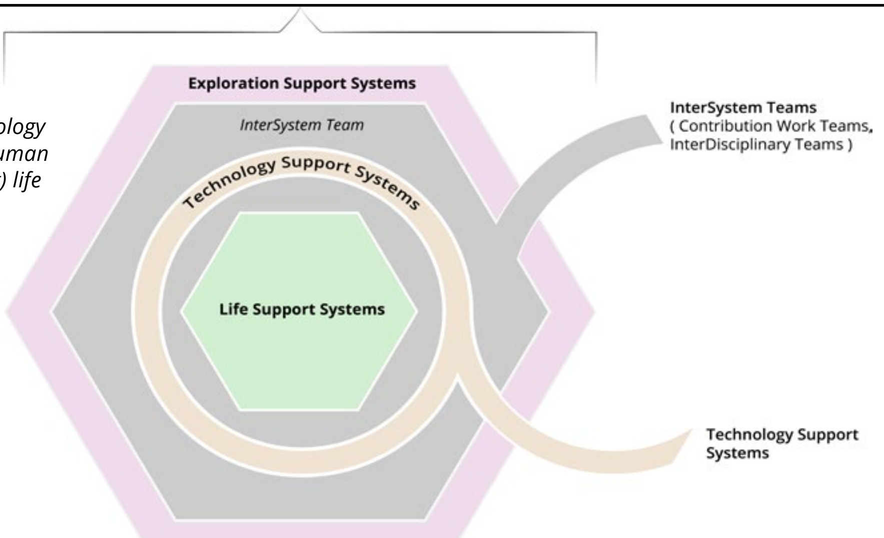
Keywords: technology, technology accounting, technology readiness, technology development, technology operation,

Abstract

All technical-based platforms must account for technology. Society, as a socio-technical system, must account for technology. Technology is an enabling element in society; it enables doing more with less. Technology can be accounted for through technology surveys. In the market, technology may be is considered defensible property. In a community-type society, technology is a tool for well-being. Technology is accounted for in order to optimize societal configuration. Technologies can be compared between. A solution within the decision system can compare the technical requirements and consequences of different technologies. The orientational value system within the decision system will compare analyze the technologies in relation to formalized desirable conditions. Some technologies are less well understood and developed than others. Technology can be identified by the manner in which the technology is actually used by individuals. Technology can be accounted for by the work done by scientists and engineers (as developers). The diffusion of technology through cities in a given society can be accounted for, by at least, resource availability, knowledge availability, and local [cultural] values. Technology exists to improve human well-being, including access to goods and services.

Graphical Abstract

Figure 30. *The integration of technology into a habitat service platform for human human fulfillment, involving (at least) life and exploration support.*



1 What is technology

NOTE: *Community articulates reasons for using technology, while applying technology systematically for human and ecological benefit. In early 21st century society technology is selected and applied ad hoc and for profit.*

The word technology comes from the Greek word "tekhnologia" (or, "tekne"), which means: art, skill, craft in work; method, system, an art, a system or method of making or doing. "Craft" originally meant "weaving" or "fabricating". technology is a functional subsystem of modern society that observes the world of tools, techniques and applications using the code (hard material code and/or soft digital code; or genetic code).

Today, technology may be defined as (i.e., technology is):

1. An expression of meaning through values that encodes functionality into a specific configuration of matter that processes information as energy. Technology is an expression of meaning that expresses values and encodes functionality in a specific, materially usable system.
2. The intentional application of knowledge. If technology is applied knowledge, then habitat service system represent the applied encoding of technology into a habitat.
3. The applied result of the logical ordering of factual technical relationships; technology is applied knowledge.
4. The practical application of knowledge into a construction for a function. It refers to a technological process, method, or technique such as machinery, equipment or software needed for a service or process to achieve its purpose. Even a practice or process can be a technology, although in common parlance, people have a tendency to think of technology solely as something which is material.
5. Some thing with a function or utility to it. Technology is simply the application of [accurate] knowledge toward the extension of function.
6. A systematic creation that allows an organism to do a task more efficiently than using its body alone.
7. An engineered creation.
8. The result of effectively re-structuring an environment through intention.
9. A material object with measurable dimensions and material attributes.
10. A procedural model (or procedural object) with measurable affects on information and conceptual attributes.

Technology is [systematically] built on prior verified and understood patterns of relationship in a commonly objective, existent reality. Technical processes underlay every designed structure in the real world. At a societal level, technology is that which is tested and works.

All technological systems are:

1. Purposeful.
2. Built on/from technical principles.
3. Subject to off-normal events, including accidents and faults, due to both component malfunctions and unforeseen/foreseen external influences. Therein, some technology requires additional technology to minimize the likelihood and impact of accidents.

The primary functions of technology for a population include, but are not limited to:

1. Providing life support service.
2. Providing exploratory support services.
3. Providing for production (and materials re-cycling), communication, transportation, and information processing.
4. Making more efficient use of time.

The authentic use of science and technology accords many benefits, including but not limited to:

1. Improving the quality of lives by automating banal labor tasks.
2. Creating more intuitive, natural, and active learning and information systems.
3. Improving the quality of decisions and problem solving.
4. Improving the effectiveness and efficiency with which goods and services are distributed.
5. Supporting in the creation of an abundance of all goods and services. Among the most important benefit of science and technology in our community is that derived from technological automation. It is the effort to free the individual from banal labor contributions so that they may pursue their own interests, improving both themselves and the community.

NOTE: *The human organism is a technological construction; a technology for the animated expression of consciousness in material form. Wherein, consciousness has a technical and intuitive relationship to the form it inhabits.*

1.1 Technology sub-classification

INSIGHT: *Technology is not a panacea. However, it can be extremely useful in solving many kinds of problems.*

Technologies can be sub-classified according to:

1. **Structure** - The structure is the components of the design object and their relationships. A system is a structured form of organization. The structure (a.k.a., architecture) of the system designed to transform information for a purpose.
2. **Process** - The occurrence of an operational transformation (or event). A process produces a behavior [for a specific function]. The behavioral process(es) represents the attributes (or "qualities") that can be derived from the designed object's structure. A system is a form of organization that includes at least one process.
3. **Function** - The objective [purpose or goal] for the transformation within and overall existence of the system. A system is a functional form of organization.
4. **Materials** - The specific material(s) that compose the technical system (i.e., material composition).

1.2 Tools

A tool is a device that is necessary to, or aids in the performance of an operation. Tools are the manifestation and extension of consciousness. It is possible to explain how work (Read: an operation) is done through 'tools'. In the production and use of a tool there is the opportunity to apply a strategy that orients the use of a tool in a particular direction. Someone can hammer a nail into wood, but hammering continues past a particular point, then a divot may be created, and then, a hole. All tools have a contextual and orientational use. A tool's value is "put there" by the human or system that uses it.

> **Tool**
> *Noun*
> *1. A device or implement, especially one held in the hand, used to carry out a particular function.*

Tools are a structured part of a society's environment that supports sense-making, enables engineering, and facilitates servicing. There are both conceptual (informational) tools as well as physical (object) tools. A material tool is an object used to extend the ability of an individual to modify features of the surrounding material environment. A tool is the most basic type of ability extender and is comprised of a resources. A conceptual tool is a concept [model] used to extend the ability of an individual to modify features of the surrounding informational environment. Informational tools include models, programs, and algorithms.

> **CLARIFICATION:** *The terms tool and technology are often used synonymous, in other cases, a tool is a specific application or instance of a technology. In some cases, tools are physical and technologies are information.*

1.3 Technology and morality

> **INSIGHT:** *When you invent a technology you also invent the accident and/or misuse of that technology.*

Technology is amoral. What humanity chooses to do (or, not to do) with technology is a moral choice; the difference humanity creates in its environment is a moral (or "ethical") decision, that can be resolved via a direction, orientation, and approach to its decisioning. It is what technologies we create and what we do with technology that makes it moral (fulfilling) or immoral (unfulfilling).

When we perceives technologies taking us in "dangerous" directions, consider that maybe it is really our way of life, and our lifestyle, that is taking us in a dangerous direction. We are just using technologies in ways that we couldn't before (because technology is allowing us to do more of what we are doing already), and that is where there is danger.

Engineered creations will take on the biases and standards, the intentions, of the socio-economic system in which they have been designed and will be utilized. Technologies created and applied in a capitalist system will have a capitalist bias. Alternatively, technologies created and applied in community will likely maintain standards that orient all of humanity toward greater fulfillment and clarity of perception.

Human fulfillment is more important than technological progress and innovation. Societies that prioritize technological advancement over human fulfillment are likely to forget that the situations in which innovation and technological advancement are likely to align with fulfillment are the situations where creators and users can freely and visibly decide upon which innovations to encode (i.e., "incorporate") into their lives. Some societies put too much emphasis on innovation as a goal (or "economic growth" and "entrepreneurship"), which is to take for granted that innovation is always good for human well-being and fulfillment. In the market, innovations and products serve the (for profit and power) interests of market entities - they have a market/capitalist/State bias. Conceptually speaking, technology is neutral. For example, with electricity "you" can kill someone or make dinner for someone. However, specific technologies can be evaluated as setting up conditions that orient more greatly toward or away from fulfillment. For example, technologies that malfunction easily are likely to setup suboptimal resource usages, which has consequence for societal orientation as a whole. A certain kind of technology and/or its implementation can be seen to lead to certain kinds of effects. A given kind of technology can establish conditions that are not morally neutral. In a community-type society, technology is developed and applied through community-based value standards.

One might put oneself in the position of technology itself, and then ask oneself, "What would I do if I was this technology?" For example, "What would I do if I were a coffee maker, a bridge, a rifle, or a nuclear bomb?" We can imagine what these technologies would do if they "wanted" to be applied.

It must be noted here that material technology is just a piece of the modern sustainability puzzle. Solving the systemic challenges facing our global community requires context and an accurate value orientation in addition to sustainable conceptual and technological solutions. Technology is not sufficient to fix our problems; we need a moral organizational architecture. Technology without morality and intrinsic motivation is likely to promote apathetic idleness.

2 The technology development matrix

A.k.a., Technology readiness matrix, technology readiness level, etc.

The technology development matrix (TDM) is an interactive visual matrix designed to track and facilitate the development of those technologies that are necessary for human life to thrive in community. The TDM is a checklist and meta-information source of what technologies, systems and capabilities are available to build a critical path to human fulfillment. The availability of this information allows anyone to get involved in tackling the difficulties and challenges associated with technological development. The TDM could be used as a "punch list" for building the material construction of a city in community.

By accessing the matrix anyone can see who is working on which technology. If nobody is on a technology of interest to you, then you drop in your abstract, your concept, and contact information. The matrix is a view into the technological possibilities and capabilities of the community.

Technology matrices are used for:

1. Decisioning
2. Planning resource flows.
3. Planning maintenance.
4. Planning replacement (planning obselesence)

Generally speaking, technology development has three characteristics:

- It is the process of developing and demonstrating new or unproven technology.
- It is the application of existing technology to new or different uses, or
- It is the combination of existing and proven technology to achieve a specific goal.

The TDM also identifies the readiness levels of each technology.

Readiness refers to time. Specifically it means ready for operations at the present time. Level refers to the level of maturity of equipment. Equipment that is already being used for the same function in the same environment has a higher level of maturity than equipment that is still being developed. The levels are a nine-point scale based on a qualitative assessment of maturity.

Technology Readiness Level (TRL) is an index to measure the development and usability of an evolving technology. It measures how ready equipment is for use now in an operating service. A technology's "readiness level" (TRL) refers to its phase of existence. The primary purpose of using technology readiness levels (TRLs) is to inform the resolution of a decision space concerning the development and transitioning of technology. The TRL index scale goes from 1-9.

- TRL 1-3 = red, a theoretical concept
- TRL 3-6 = yellow, is being tested in the lab
- TRL 6-9 = green, is being applied

Almost all the TRL scale developers and users in various perceive TRL 6 to be a major transition from research and experiment to real life implementation and operation. At TRL 6, a representative model, prototype or system, which would go well beyond an ad hoc discrete component level breadboard, must be tested in a relevant environment. If the only relevant environment to show progress is the operational environment, then the validation must be demonstrated in operational environment. At TRL 6, several (or many) new technologies will typically be integrated into the demonstration so a working, sub-scale (but scaleable) model of the system should be successfully demonstrated.

Note, however, that the idea of a "technology readiness level" does not apply if the objective of a project is to research scientific principles.

2.1 Technology application levels

The following are reference points for reading and usage of the technology application level index:

Table 3. *Technology application levels: from absent to stored.*

Technology application level	Indicators
Absent	Limited to no solution plans in this area. Limited to no capabilities in this area.
Exploring	Inquiring into phenomena in this area (research; as in, the Exploratory Service System for the Habitat Service System). Inquiring into solution plans in this area (as in, Solution Inquiry within the Decision System).
Enablable	Application of technology can be integrated into the existing state of the habitat service system.
Connected	Application of technology is integrated into the existing state of the habitat service system.
Stored ("Retired")	Technology has been removed from application.

2.2 Technology readiness levels

> **INSIGHT:** *Capitalism hasn't given "you" any technology. Instead, capitalism gives "you" the need to buy and sell technology. In capitalism, there is willful withholding of technology and efficiency to remain competitive in the market.*

The following are reference points for reading and usage of the technology readiness level index:

1. **A TRL number is obtained once the description in the diagram has been achieved.** For example, when a technology successfully achieves TRL 5, it does not move to TRL 6. Therefore, reporting TRL 6 should be conclusively done with TRL 6 activities and validation.
2. **If a technology consists of various sub-technologies, its TRL number is the lowest of all.** A technology may depend on a number of technologies or sub-systems with their own TRLs. Then, the ultimate technology is assigned with the lowest TRL number among them.
3. **When an element of a technology is altered, its previous TRL number becomes invalid.** When one replaces, eliminates, or adds a major component or part even in a TRL-9 technology, everything starts all over again from the appropriate TRL usually between 1-4.
4. **When the primary use of a technology changes, its previous TRL number becomes invalid.** If you try to integrate (launch) a technology (product) into a different system (market), you cannot claim its previous TRL number any more. You should work through TRL validations again.
5. **If a technology spends too much time at a given TRL, its TRL number becomes invalid.** As time goes by, even a TRL 9 technology requires re-confirmation due to the probable changes in the conditions (i.e. know-how, climactic environment) that its previous TRL number is based on.
6. **Activities and progress through TRLs are not time-boxed.** Some technologies may evolve faster

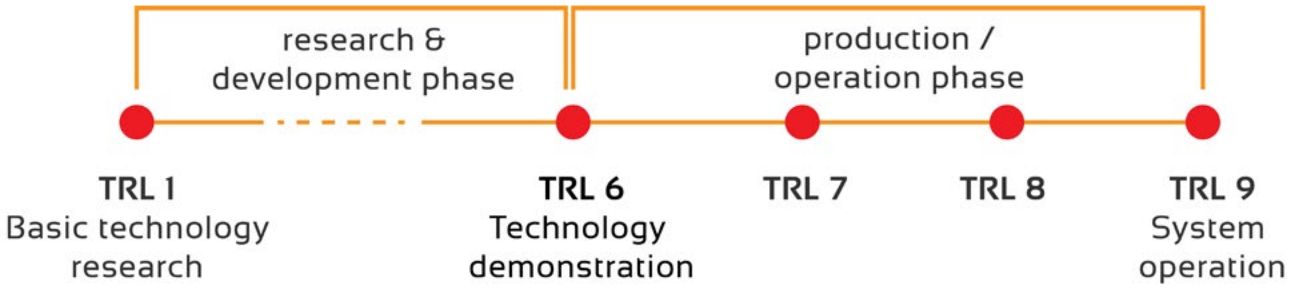


Figure 31. *Technology readiness level production/operation phase.*

than others. Or, a particular technology may pass some levels in weeks but the others in years.

7. **TRL activities and validation criteria are subjected to change over time.** You cannot precisely specify TRL 8 requirements for a project while you are at TRL 2 stage and keep them the same along the way. Inspection and adaptation are needed.

Important terms to know when using the technology readiness level index include:

1. **Prototype:** A physical or virtual model used to evaluate the technical or manufacturing feasibility or utility of a particular technology or process, concept, end item, or system.
2. **Model:** A functional form of a system, generally reduced in scale, near or at operational specification. Models can be sufficiently hardened to allow demonstration of the technical and operational capabilities required of the final system.
3. **Demonstration/Pilot:** Actions aiming to validate the technical and ecological viability of a new or improved technology, product, process, service or solution in an operational (or near to operational) environment.
4. **Critical technology element:** A new or novel component that a technology or system depends on to achieve successful development or to successfully meet a system operational threshold requirement.
5. **Relevant environment:** Testing environment that simulates the key aspects of the operational environment.
6. **Operational environment:** Environment that addresses all of the operational requirements and specifications required of the final system, including platform/packaging.

2.3 Technology obsolescence levels

The general technology obsolescence levels are:

1. Obsolescence not an issue.
2. Technology is the state-of-the practice; emerging technology could integrate or replace.
3. Technology is outdated and use should be avoided in new systems; spare parts supply is scarce.

In industry, technology primarily becomes obsolete when another technology becomes more cost effective for the functionality provided -- emerging technologies compete with established technologies for market share over a particular [service] functionality. In community, new discoveries and engineered systems render old technologies obsolete. In a market, along with technology readiness there is also something called a “market readiness” level (MRL) - peoples desire and resources to purchase a technology (i.e., the readiness of people to consume the technology).

1. Technology name.
2. Technology material composition.
3. Technology material configuration.
4. Technology operational usage requirements.
5. Technology safety requirements.
6. Video of technology in use.
7. Alternative technologies.

3 Technology phasing

The issue of phasing technology into a societal system is often called, "the infrastructure problem".

4 Technological automation

4.1 What can be automated?

Some physical motions can be automated, and others cannot. All software is a form of automation; the automation of computation.

4.1 What technological productivity benefits can be realized through automation?

Technological productivity can be calculated as:

- Productivity = what is produced / # of hrs takes to produce.

4.2 Technological unemployment

> **INSIGHT:** *Social progress can masquerades as technological advancement. Technology can lead to greater apathy and acquiescence.*

Technological unemployment is a market-State concept that refers to the occurrence of technology displacing workers by substituting their cognitive and fine motor control with machines.

5 Technological objects

No content here yet.

Scholarly references

- *Definition of the TRLs and their criteria of assessment, ISO 16290:2013.* (2013). ISO. [spacewx.com]
- *Department of homeland security science and technology readiness level calculator (ver 1.1).* (2009). Homeland Security Institute. [ansr.org]
- *Guide to Technology Readiness Levels for the NDA Estate and its Supply Chain*. (2014). Nuclear Decommissioning Authority, 2014. [assets.publishing.service.gov.uk]
- Final Report of the NASA Technology Readiness Assessment (TRA) Study Team. (2016). U.S. NASA. [ntrs.nasa.gov]
- *Technology Readiness Assessment (TRA) Guidance.* (2011). U.S. Department of Defense. [apps.dtic.mil]
- *Technology readiness assessment guide*. (2011). U.S. Department of Energy. [lbl.gov] [directives.doe.gov]
- *Technology readiness assessment guide*. (2016). U.S. GAO. [gao.gov]
- *Technology readiness levels handbook for space applications*. (2008). European Space Agency. [artes.esa.int]

Book references

- Ford, M. (2016). *Rise of the Robots: Technology and the Threat of a Jobless Future*. Basic Book.
- Ford, M. (2009). *The Lights in the Tunnel: Automation, Accelerating Technology and the Economy of the Future*. CreateSpace Independent Publishing Platform.
- Pistono, F. (2012). *Robots Will Steal Your Job, But That's OK: how to survive the economic collapse and be happy*. CreateSpace Independent Publishing Platform.

TABLES

Table 4. Technology: *Technology readiness levels.*

Number	Technology Readiness Level	Description
1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into technology's basic properties.
2	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3	Analytical and experimental critical function and/or characteristic proof of concept	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity"compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.
5	Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in simulated environment. Examples include "high fidelity" laboratory integration of components.
6	System/subsystem model or prototype demonstration in relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for level 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in a simulated operational environment.
7	System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from level 6, requiring the demonstration of an actual system prototype in an operational environment. Examples include testing the prototype in a test bed aircraft.
8	Actual system completed and qualified through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this level represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9	Actual system proven through successful operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Table 5. *Technology > Readiness: Technology readiness level index.*

Application	Technology Readiness Level	Definition	Description	Results from
Pre-existing knowledge	1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.	Published research that identifies the principles that underlie this technology. References to who, where, when.
Technology research	2	Technology concept and/or application formulated - conceptual design formulated	Once basic principles are observed, practical applications can be designed (i.e., "invented"). Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies. The step up from TRL 1 to TRL 2 moves the ideas from pure to applied research. Most of the work is analytical or paper studies with the emphasis on understanding the science better. Experimental work is designed to corroborate the basic scientific observations made during TRL 1 work.	Publications or other references that outline the application being considered and that provide analysis to support the concept.

TABLES

Application	Technology Readiness Level	Definition	Description	Results from
Research to prove feasibility	3	Analytical and experimental critical function and/ or characteristic proof of concept - conceptual design tested analytically or experimentally "Concept defined"	Active research and development (R&D). This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative. At TRL 3 the work has moved beyond the paper phase to experimental work that verifies that the concept works as expected on simulants. Components of the technology are validated, but there is no attempt to integrate the components into a complete system. Modeling and simulation may be used to complement physical experiments.	Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. References to who, where, and when these tests and comparisons were performed.
Technology development	4	Component and/ or system validation in laboratory environment - critical function/characteristic demonstration "Concept defined"	Basic technological components are integrated to establish that they will work together. This is relatively “low fidelity” compared with the eventual system. TRL 4-6 represent the bridge from scientific research to engineering. TRL 4 is the first step in determining whether the individual components will work together as a system.	System concepts that have been considered and results from testing laboratory-scale. Reference to who did this work and when. Provide an estimate of how test results differ from the expected system performance goals.
Technology development	5	Component and/ or system validation tested in relevant environment "Proof of concept validated"	The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. The major difference between TRL 4 and 5 is the increase in the fidelity of the system and environment to the actual application. The system tested is almost prototypical.	Results from testing are integrated with other supporting elements in a simulated operational environment. How does the “relevant environment” differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Was the system refined to more nearly match the expected system goals?

TABLES

Application	Technology Readiness Level	Definition	Description	Results from
Technology demonstration	6	System/subsystem model or prototype demonstration in relevant environment - prototype/engineering model tested in relevant environment "Proof of concept validated"	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment. Represents a major step up in a technology's demonstrated readiness. Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. TRL 6 begins true engineering development of the technology as an operational system. The major difference between TRL 5 and 6 is the step up from laboratory scale to engineering scale and the determination of scaling factors that will enable design of the operating system. The prototype should be capable of performing all the functions that will be required of the operational system. The operating environment for the testing should closely represent the actual operating environment. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.	Engineering-scale models or prototypes are tested in a relevant environment. Results from engineering scale testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
System integration	7	System prototype demonstration in relevant operational environment - engineering model tested under relevant operational conditions "Demonstrated"	Prototype near (or at) planned operational system. A similar (prototypical) system is demonstrated in a relevant operational environment. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment.	Results from testing a prototype system in an operational environment. Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
	8	Actual system completed through testing in an operational environment "Qualified"	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents The technology meets its designed specification.	Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before finalizing the design?
System operation	9	Actual system operated successfully through expected conditions "Proven"	The technology is in its integrated form (i.e., integrated into a service system) and operating under the full range of expected conditions, such as those encountered in operational test and evaluation (OT&E).	OT&E data.

TABLES

Table 6. Technology > Readiness: *Data requirements for each technology readiness level.*

Criteria	Description
Structural servicability	Natural forces, strength properties
Fire safety	Fire resistance, flame spread, smoke development, toxicity, fuel load, combustibility
Habitability	Thermal properties, acoustic properties, water permeability, optical properties, hyegine, comfort, safety
Durability	Resistance to wear, weathering, adhesion of coatings, dimensional stability, mechanical properties, rheological properties
Practicality	Transport, storage on site, handling at installation, field tolerances, connections
Compatibility	Jointing materials, coatings, galvanic interaction or corrosion resistance
Maintainabilty	Compatibility of coatings, indention and puncture (patching), chemical or physical attack
Environmental impact	Resource consumption at production, life cycle impact
Aesthetics	Visual impact, customizing options, color selection, pattern selection, surface selection

Table 7. Technology > Readiness: *Technology readiness levels.*

Applications	Technology Readiness Level	Description	Requirements	Verification	Viability
Broad Range of Applications	1	1.1) Physical Principle	1.2) Needed Capability	1.3) Analytical or Experimental	N.4) Advancement to the Next Level Technical & Programmtics (N = 1-8)
	2	2.1 Basic Concept	2.2) Needed Functionality	2.3) Analytical or Experimental	
	3	3.1) Key Technology Characteristics	3.2) Basic Requirements (Family)	3.3) Simulation or Experimental	
	4	4.1) Full Technology (in the Laboratory)	4.2) Complete Requirements (Narrower Range and Interactions)	4.3) Rigorous Experimental	
Family of applications	5	5.1) Full Technology & Interactions (in a Relevant Environment)	5.2) Complete Requirements (Specific)	5.3) Rigorous Testing at Component and/or Breadboard in Relevant Family of Environment	
	6	6.1) Full Technology in System or Subsystem	6.2) Full Requirements (System or Subsystem)	6.3) Rigorous Testing at System and/or Subsystem in Relevant Environment	
Preliminary Definition for Specific Application	7	7.1) Full Technology in System or Subsystem	7.2) Full Requirements in Space Environment (System or subsystem)	7.3) In Space Demonstration	
Specific Application	8	8.1) Full Technology in System (Manufactured)	8.2) Full System and Qualification Requirements	8.3)Qualification Campaign	
	Application	9.1) Final Manufacturing & Operations Plans	9.2) Performance and Manufacturing Requirements	9.3) System Operations Verification (including life)	9.4) Failure Analysis (if needed) and/or Future

Service Accounting System

Travis A. Grant,

Affiliation contacts: *trvsgrant@gmail.com*

Version Accepted: 8 July 2022

Acceptance Event: *Project coordinator acceptance*

Last Working Integration Point: *Project coordinator integration*

Keywords: service, service accounting, servicing, service systems, habitat service, service accountability

Abstract

All social-based platforms must account for service. Society is a socio-technical system that must account for service in order for fulfillment to have meaning. Service is an enabling element in society; it enables productive, organized, repeatable, and motivated effort. Service can be accounted for through user and habitat surveys. In the market, service is sold. In the State, service is duty. In a community-type society, services are accounted for, contributed to, and operationalized. Cities are localized service systems. Services are operated by contributors for users. All services require information and objects, and therein, sufficient information and objects to result in a continuation of the service and satisfied users.

Graphical Abstract

Figure 32 on page 81

1 The unified information system

An information system is a fundamental element of a socio-technical society, because it interconnects four fundamental environments: the social and technical spaces as well as the digital (virtual) and material environments, and formalized through signals and language systems allows different actors to interact with coherency and precision. These connections are important in the production of useful projects, designs, possibilities, and simulations that are likely to generate a stable and predictable environment [for human fulfillment]. By viewing society as an information system, it is possible to formalize intentions, perceptions, and physical space in a useful and intelligent manner.

Through a unified information model it is possible to fully account for the material environment, in particular, composition and location. When composition is accounted for, then it is possible can compute various functions of the same materials. With a referential database of materials and functions it is possible to identify probable service configurations - exploring probabilistically the way in which material resources can be transformed into productive goods and services, and then back into their basic material constituents, following a sustainable cycle. Humanity can then design different material configurations of its environment and simulate their engineered experience for optimal resolution of the current habitat.

1.1 A service system

A.k.a., A productive contribution system, a production system, a socio-economic system, an access [contribution] system.

Everything which has been technically constructed into the habitat may be said to have been engineered and integrated into that which is most often referred to as a "habitat service system". Service needs become engineering requirements for a specific states and resource positions of the material system. In its base form, a service is a process of doing something for and with others -- for human fulfillment and with an Intersystem Team contributing through a Contribution Service System. The primary productions of this Contribution Service System are a Societal Specification Standard and an operating Habitat Service System(s) based on the societal standard. The Habitat Service System is the first societal=level produced [material] service system.

A service system is a complex socio-technical system. A service system is a configuration of technology and organizational networks designed to transform resources into objects that are delivered as services [through contribution] that satisfy the needs and preferences of their users. Needs are essential, of which the top level material categories are:

1. Life support needs are provided by a life support system.
2. Technology support needs are provided by a technology support system.
3. Exploratory needs are supported by an exploratory support system.

NOTE: *Societal service systems are socio-technical systems that have engineering requirements and performance requirements.*

Preferences (wants) are not essential and relate to the transformation of resources and environments that involve subjective preferance. These are voted on, and votes are processed within a value inquiry processes which facilitates the design of the newly to be resolved habitat service system state.

The emphasis is placed on the co-operative characteristic of the act of service. Service is defined as the application of skills (knowledge and tools) to the benefit of others, suggesting that service is a agreement, commitment, and action between an individual (in the community) who is also a user (in the community) that has as a beneficial/useful result, thus meeting the Social System Standard value condition of 'Contribution'.

NOTE: *A service system is more broadly labeled as a service. In other words a service system that serves a population is a service itself (i.e., it is recursive).*

In a task-based systems oriented sense, service involves at least two entities, one applying competence [at completing tasks/objectives] and another integrating the applied competences with other resources ("value-co-creation") and determining benefit. These interacting entities may be called, service systems (or, a service system). In other words, the idea of a service system involves two entities with the following inputs, processes, and outputs:

1. [Contributor] The serving entity, doing tasks with objectives, apply effort and resources. The serving entity accounts for requirements.
2. [User] The serviced entity, receiving the benefit of applied competence, and realizing a fulfillment benefit. The service entity accounts for needs.

A service system is thus a system of interacting and interdependent parts (people, and shared resources, technologies, organizations, and information) that is oriented to accept contributions by meeting the needs of the same population; by servicing fulfillment through human service contribution. A Habitat Service System's construction and operation requires an Intersystem (inter-/mulit-disciplinary) approach. Service interactions occur within environments. In a community-type society, the habitat is the location in which most service interactions occur. The habitat may be sub-divided into local habitat service systems (Local HSS).

Here, service is of actual social and material value to everyone. In order to be of actual social and material value, service is realized through the value condition of 'cooperation' (a stabilizing value in the Value System detailed in the Social System) within macro-decisioning and macro-coordination. In this sense, the material service system is an extension of a human contribution-based service system; because, the humans contribute so that habitat service fulfillment continues through socio-technical [habitat] service systems.

Broadly speaking, service is the application of resources, including individual human resources (competences, skills, and knowledge) and shared phsyical and informational resources, to operate systems and make changes to systems that have fulfillment (Read: beneficial) objectives (i.e., "value") for another (system). Value is improvement in a system, or the fulfillment of an individual, as determined by a decision system or by the system's ability to fit an environment.

Service systems are made up of resources included within activities. The two primary resource types/ activities are:

1. **Operant resources** that perform actions on other resources.
   - Operant resources can act on other resources (including other operant resources) to create change.
2. **Operand resources** that are operated on.

NOTE: *Without an operant resource there is no service system.*

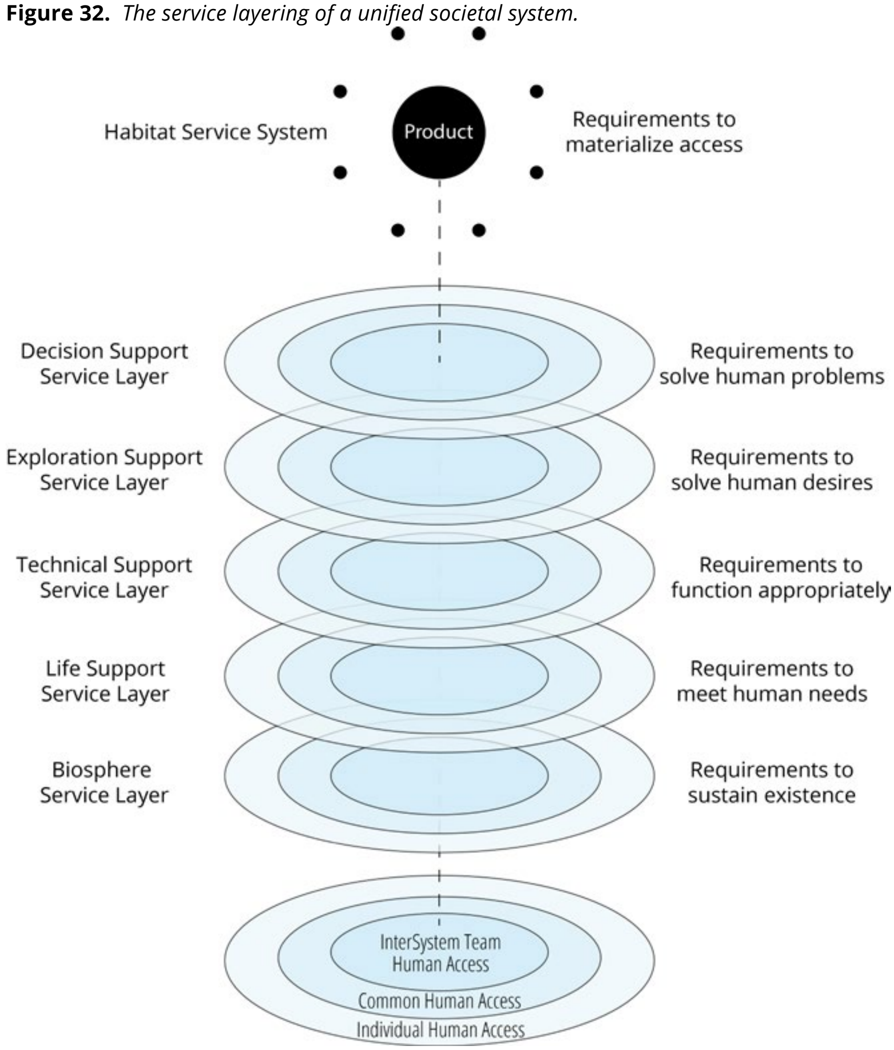
Determining which resources are operand and which are operant depends on the position and orientation of the system deciding it. A physical tool, such as a "hydraulic press", is an operant resource for the service production system, because in this case it that creates tablets out of a powdered chemical. In this case, the tablet is an operant resource, because it is used to clean dishes in a dishwasher. Additionally, the "hydraulic press" may be the operand resource for a member of the InterSystem Team or an [automated] habitat service sub-system (e.g., factory production service robot). Operant resources act on operand resources from the resolution iof a deciding service system.

Note here that human contribution is an operant resource and individuals must act to apply operand resource through, at the very least, a proposal for contribution that is agreed upon and committed to, and which leads to the fulfillment of all. A service system is a configuration of resources, and so, it is also a type of resource itself. In fact, it may be an operand resource for another service system. For example, life support is part of the habitat service system. (Spohrer et al., 2008)

Note here that the ability to share the supply of (i.e., "pool") resources across a set of combined service systems is an essential component of community operation. A cooperative of using contributors agree to share common resources, commonly produced and used tools, and common information to meet a set of fulfillment objectives defined as service system requirements. Sharing is advantageous for the overall service system.

It is possible to decide the engineering of and evaluation of a service system; and, this process is generally called, "utility". A service system that doesn't

Figure 32. *The service layering of a unified societal system.*



have utility is not useful to its users.

The worldview of [common] service-dominant logic stands in sharp contrast to the worldview of the property-dominant logic of the early 21st century, as it holds service - the application of competences and resources for benefit of others - rather than property by means of competition (predation), to be the fundamental basis of economic operation. Within the service-oriented worldview, it is suggested the axiomatic material abstraction is the service system, which is a configuration of people, technologies, information, and other resources that interact to create mutual fulfillment. When this happens at the city level, within a habitat(s), it is reasonably labeled a, habitat service system. Herein, humans contribute, necessarily, to the existence and persistence of a [habitat] service system.

As a system, the habitat service system may be decomposed to a set of primary habitat service sub-systems, each of which meets a unique primary category need of the population (e.g., life, technology, exploratory). In this context, the organizational view of a service system is sometimes known as service system mapping (although it has many other names).

Note here that many systems can be viewed as service systems, including families, cities, and working groups, among many others.

2 Service system carrying capacity

NOTE: *Population problems have a horrible way of resolving themselves.*

Carrying capacity is a term that relates to the primary service systems in the habitat. Each service system has a capacity determined by its inputs, process, and outputs. The outputs of each service system are calculated to sufficiently fulfill the population, while providing a storage buffer for safety. For example, all cities will be designed with a buffer capacity for housing. Therein, something akin to 3-5% (*an estimate, accurate figures to be determined by decisioning*) of the dwelling will remain unoccupied. This allows for:

1. Expansion of the population,
2. Always available housing alternatives; and
3. Possible emergency housing in case of a disaster.

One might imagine 100% capacity as the most effective strategy for occupation of a locale, but in the context of survival in a larger ecology, a buffering strategy for occupation and usage of a service system is most efficient. Buffering means that there is a lessening or moderating of the impact of something. The buffering part of each service system provides access to resources and other materials in case of an unaccounted for demand or incident. When the precautionary principle is applied to habitat service functionality, then it means to have enough of something so that you have another one if the first one breaks or if more are immediately needed.

Businesses in the market prefer to operate their systems as close to full capacity (i.e., “peak capacity”) as possible to maximize their revenues. In community, we design for service and ecological capacity, and we operate within that set capacity threshold with a buffer for risk. In community, there is no incentive to operate at peak capacity. Instead, service operations in community fluctuate directly with demand and participation - they are designed by the user, for the user.

It is also relevant to point out here that populations may actually begin migration within the city network, which may seasonally shift the population sizes of various community-cities.

Any service system may be reconfigured for a new function and capacity.

Allowing expansion sounds like a contradiction to total city design. We can duplicate cities, but to have them undergo expansion may be poor design and not even possible in a sustainable system.

In order to determine a structure’s functional capacity, the following must be known (What is the functional capacity of a structure?):

- What is the material composition of a structure?
- What is its engineered configuration?

- What is the functionality that it encodes?
- What are the structure's interdependencies?
- What is the affect of the structure on its environment?

3 Common city services

Common city services found in most habitat service systems throughout community include, but are not limited to:

> *Note that this list is highly limited in detail and scope. This is more of an overview of the services that are available and more fully described in the service specific sections later in this document. Currently, this list acts like more of a comparison between common services in community and "services" the market-State (the second list below).*

1. **Residential services**
2. Accommodation
3. Eating and drinking
4. Clothing and accessories
5. Household and office supplies
6. **Cultivation**
7. Food cultivation
8. Materials cultivation
9. Gardening
10. **Medical services**
11. Emergency medical care
12. Medical safety services
13. Medicines production
14. Life stage care
15. **Energy and power services**
16. Heating, ventilation and cooling (HVAC)
17. **Construction/materialization services**
18. Production (including extractive)
19. Recycling
20. Maintenance and repair
21. **Information services**
22. Computing services
23. Information storage and processing
24. **Communications services**
25. **Transport services**
26. Rapid transport (vehicles, stations, and infrastructure; road and rail)
27. Personal transport
28. Walking
29. Water
30. Distribution
31. Storage
32. **Recreational services**
33. Bodies of water
34. Landscape features
35. Outdoor pursuits
36. Sports and entertainment
37. Sports complex
38. Venues, stage and screen
39. Quite and contemplation pursuits

40. Botanical and zoological cultivation attractions
41. **Science and research services**
42. **Technological development services**
43. **Learning services**
44. Team mentoring
45. Learning facilitation

Services in the market-State that are absent in community include, but are not limited to:

1. **Commercial services**
2. Consultancies
3. Contract services
4. Employment and career agencies
5. Hire services
6. Advertising and marketing
7. Legal and financial services
8. Property services
9. Gambling
10. **Schooling services**
11. **Retail services**
12. **Government services**
13. Policing service

Scholarly references

- Spohrer, J., Vargo, S.L., et al. (2008). *The Service System is the Basic Abstraction of Service Science*. Proceedings of the 41st Hawaii International Conference on System Sciences. DOI: 10.1.1.109.1275 [citeseerx.ist.psu.edu]

TABLES

Table 8. Service Accounting*: Material habitat cycling human design solution.*

Natural and induced environment factors	Factors that create the physical environment surrounding a team	Human needs of the system	Interface design between human and system
Noise level	Decor	Mutual [threshold] existence (availability = mutual level of availability)	Identifiability
Felt uplift level	Aesthetic level	Availability of sensory stimulation	Information systems and decision support
Vibration level	Anthropometric accommodations	Availability of access	Standardization
Humidity level	Habitat volume	Availability of operation	Re-materialization
Illumination level	Location and orientation aids	Availability of operation	Recycling and waste management
CO2	Transportation and communication paths	Availability of sensory stimulation	Control panels, input devices
Air flow	Fabrication systems and material cycling systems	Availability of information and physical inter-access	Information technology tool availability
Oxygen level (and level of other atmospheric particulate matter)	Windows	Availability of life support	Hardware, software, and InterSystem Team contribution support
Aromatic sensation; Odor	Illumination (as ambient lighting)	Availability of decision support	Availability of InterSystem Team surface area
Toxic: Substances level		Availability of technology support	Availability of Common Access surface area
Atmospheric pressure level		Availability of exploration support	Availability of Personal Access surface area
Radiation exposure level, etc.			Human habitat integration
			Mobility and constraints availability and quality
			Caution and warning functionality
			Human and/or robotics and automation integration

Materials Accounting System

Travis A. Grant,

Affiliation contacts: *trvsgrant@gmail.com*

Version Accepted: 8 July 2022

Acceptance Event: *Project coordinator acceptance*

Last Working Integration Point: *Project coordinator integration*

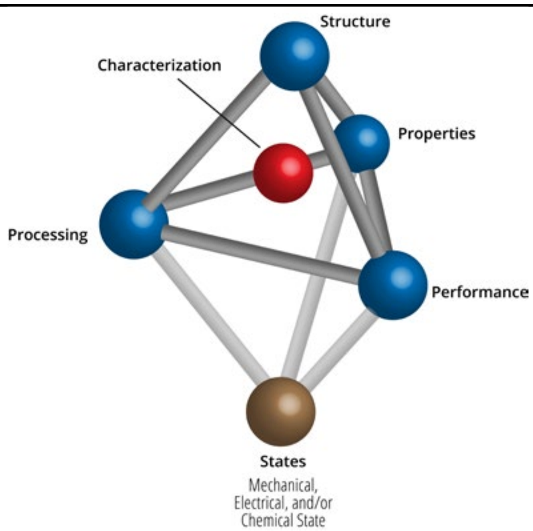
Keywords: material science, material science system, materials accounting, material flow, material composition

Abstract

A material system is a physical object in the world. A material system is naturally composed of materials (the synonyms of which are object, shape and surface). There are different material types, different material compositions, different material flows, and different methods of materializing. To intentionally reconfigure society at the material level, the materials of which society is composed must be engineered to meet societal requirements. When it is necessary to know the objects (of decisioning), then a materials system explication becomes essential to decision resolution. Materials can be combined and reconfiguring, and in doing so, their object properties can be changed (e.g., a neodymium iron core can be transformed into a magnet). A materials system is a repository of real objects (materials), their usages, and how they behave. There is an interrelationship among all objects in a material system. In some cases the tension of interrelationships is very weak, and at other times, there is a high tension. Materials selection is significant to solution determination. A complete accounting of material resources is essential if decisions are to be optimal.

Graphical Abstract

Figure 33. *Materials science characterization tetrahedron model shows how one aspect of a material affects the rest of the properties. If the structure is altered, the properties, characterization of atoms, processing, and performance will all be altered. Illustrates all the aspects of a material that an engineer should look for and understand.*



1 Introduction

The physical world is made of matter. All matter has physical presence, which may be sub-characterized as having ‘object’ and ‘location’ (i.e., distance from every object in the universe). When matter is used for human purposes, it is called a ‘material’. Therein, materials science is the design and discovery of new materials. All materials (matter) are made of chemicals. A narrow definition of material is any physical substances that things can be made from.

1.1 Materials versus products

A.k.a., Supplies, resources.

The terms ‘products’ (‘goods’) and ‘materials’ are sometimes used as if they are interchangeable, however, there are differences between them determined by what they are made of, how they are finished, and whether they are offered for use (or, sale in the market). Products are processed, finished items. That is, they are manufactured combinations of materials and perhaps other products, processed to create finished or intermediary items. 'Products' are generally distinguished from. ‘Materials’ which are raw, unprocessed substances such as sand, salt, and so on. Note here that products and materials are distinguished from ‘services’, which are activities. The names for service-type activities generally end with an -ion suffix (or, -ing and -ance), such as consultation, maintenance, installation, watering, and architecting.

Very broadly the difference between materials and products is that:

1. **Materials (resources)** - raw, unprocessed substances such as sand, salt, and so on.
2. **Products ("goods")** - processed, finished items that are offered for use (or, sale in the market). That is, they are manufactured combinations of materials and perhaps other products, processed to create usable items.

NOTE: *In some parlance, a "good" may be classified as something that is in someone's possession.*

However, this apparently clear difference becomes more complex when applied to intermediary items, composite materials (such as adhesives), to finished materials (such as processed timber), to unfinished products, and so on. For example, steel, whilst it has been processed, might be considered to be a material, whilst a steel beam, which is the same material but in a different form might be considered to be a product. And yet, steel beams may be an item on an architectural materials list.

1.2 Materials supply chain

A supply chain is the breakdown and traceability of products and services, organisations, logistics, people, activities, information and resources that transform raw materials into a finished product that is fit for its purpose. In other words, supply chain is a network between organizations that supply, produce, and distribute a specific product to the final user. Notice here the similarity between the idea of an 'economic system' and the concept of a 'supply chain'. An 'economic system' is the acquisition and transformation of resources into needed products (goods) and services. Supply chain coordination (supply chain management) is the coordination of the flow of resources into goods and services, and it includes all processes that transform raw materials into final products. In the market-State, the "supply chain" is defined by the interconnected hierarchy of supply, manufacturing, distribution, and sales businesses, and their associated contracts, necessary to procure a material or built asset.

There are no businesses in a community-type society. A community-type society maintains a fully integrated supply chain. An integrated supply chain is an optimal supply chain, because it maintains the condition of efficiency through cooperation and collaboration (as opposed to scarcity; i.e., no use of money and no competition).

In the market-State, supply chains can be vertically and horizontally integrated. Horizontal integration and vertical integration are competitive strategies that companies use to consolidate their position among competitors:

1. **Vertical integration:** the process of acquiring business operations within the same production vertical. A company that opts for vertical integration takes complete control over one or more stages in the production or distribution of a product. When one organisation in a supply chain moves into a different stage of that supply chain, either by starting its own business or by acquiring an existing one.
2. **Horizontal integration** - the acquisition of a related business. A company that opts for horizontal integration will take over another company that operates at the same level of the value chain in an industry.

1.3 Classification of matter

A.k.a., Classification of material objects.

All matter has the characteristics of:

1. State of matter (a.k.a., phase of matter):
   A. Solid.
   B. Liquid.
   C. Gas.
   D. Plasma.

   E. Bose-Einstein Condensate.
2. Contains carbon:
   A. Organic material (contains all carbon).
   B. Inorganic material (does not contain carbon).
   C. Mixed/hybrid material (contains some carbon).
3. Purity:
   A. Pure substances.
   B. Impure substances (a.k.a., mixtures).
4. Changes
   A. Physical.
   B. Chemical.
5. Properties:
   A. Interaction properties.
   B. Flow properties.

1.3.6 Composition of materials

A.k.a., Composition of matter.

Matter can be classified in terms of its composition, down to the axiomatic atomic (periodic) level of the material environment.

In this way, matter can be classified as:

1. Pure matter - All matter can be classified as either a pure substance or a mixture.
   A. Element[al] - the pure element. An element is matter made up of one type of atom.
   B. Compound - are substances that are made up of two or more elements physically bonded together.
2. Mixture [of matter] - A mixture is two or more substances (elements or compounds) that are mixed, but are not chemically combined. If they were chemically combined, then they would be a pure matter compound.
   A. Homogeneous mixture - having visibly indistinguishable parts (the same, uniform, throughout).
   B. Heterogeneous mixture - having visibly indistinguishable parts (not uniform throughout).

1.3.7 Matter phase transitioning

A.k.a., Transition of matter.

When matter changes from one state to another it is called a phase transition.

Examples of common matter phase transitions include:

1. **Deposition** - bas to solid phase transitions.
   A. For example, water vapor to ice - Water vapor transforms directly into ice without becoming a liquid, a process that often occurs on windows during the winter months.
   B. For example, physical vapor to film - Thin layers of material known as "film" are deposited onto a surface using a vaporized form of the film.
2. **Condensation** - gas to liquid phase transitions.
   A. For example, water vapor to dew - Water vapor turns from a gas into a liquid, such as dew on the morning grass.
   B. For example, water vapor to liquid water - Water vapor fogs up glasses when moving into a warm room after being in the cold
3. **Vaporization** - liquid to gas phase transitions.
   A. For example, water to steam - Water is vaporized when it is boiled on the stove to cook some pasta, and much of it forms into a thick steam.
   B. For example, water evaporates - Water evaporates from a puddle or a pool during a hot summer's day.
4. **Freezing** - liquid to solid phase transitions.
   A. For example, water to ice - Water becomes cold enough that it turns into ice. In fact, every known liquid (except for helium) is known to freeze in low enough temperatures.
   B. For example, liquid to crystals - Most liquids freeze by a process that is known as "crystallization," whereby the liquid forms into what is known in the scientific world as a "crystalline solid."
5. **Melting** - solid to liquid phase transitions.
   A. For example, heating metal in a smelt to a high enough temperature that it turns into a liquid.
   B. For example, heating chocolate in an oven to turn it into a liquid
6. **Sublimation** - solid to gas phase transitions. In most cases, solids turn into gases only after an intermediate liquid state.

1.3.8 Matter purity

In concern to purity, matter can be classified as:

1. **Pure substances** - matter that cannot be separated by physical means.
   A. **Element** - contains only one kind of atom. Elements cannot be chemically decomposed.
   B. **Compound** - contains two or more types of atoms in whole number ratios. Compounds can be chemically decomposed.
2. **Mixture (impure substance)** - matter that can be separated by physical means.
   A. **Homogeneous mixture (a.k.a., solution)** - uniform throughout.

B. **Heterogeneous mixture** - non-uniform distribution.
   1. **Colloids** - Particle size: 1-1000 nm, dispersed; large molecules or aggregates; and particles do not settle out of the dispersing medium due to the effects of gravity.
   2. **Suspensions** - particle size is over 1000 nm, suspended; large particles or aggregates; and particles settle out of the dispersing medium due to the effects of gravity.

1.3.9 Material properties

A.k.a., Materials factoring, properties of matter.

Materials factoring includes:

1. Physical properties
   A. Chemical
   B. Electrical
   C. Magnetic
   D. Electromagnetic (a.k.a., optical)
2. Composition
3. Decomposition – including, wearing due to use and natural decomposition
4. Material resource flow
5. Contamination
6. Integration and De-integration

NOTE: *Natural objects are those not made by a human hand or machine.*

1.3.10 Forces on materials

The common mechanical forces on objects composed of materials include:

1. Squeeze.
2. Stretch.
3. Bend.
4. Slide.
5. Twist.
6. Pressure.
7. Tension.

1.4 Matter sub-types

Additional matter types include, but are not limited to:

1. **Inorganic materials (inorganic compounds) -** most inorganic compounds do not contain carbon. Inorganic materials are generally derived from non-living sources, such as rocks or minerals, and encompass such categories as glass, ceramics, metals, minerals, clays, and metals.
2. **Organic materials (a.k.a., organic compounds, organic matrices)** - contain carbon and carbon-hydrogen bonds. They are solids composed of long molecular chains. For example, polymers, hydrogels, brushes, lipids, proteins, carbohydrates, nucleic acids.
3. **Hybrid materials** - incorporate both organic and inorganic constituents.
4. **Biological materials (a.k.a., biological compounds)** - self-organization of materials from the molecular level up. The basic building blocks are start with the amino acids and proceed to polypeptides, polysaccharides, and polypeptides–saccharides.
5. **Regenerative matter (a.k.a., living matter, biology)** - life and other biologically living materials.
6. **Elemental matter (a.k.a., non-living matter)** - the elements [of matter].
7. **Decaying matter**
   A. **Decomposing matter** - prior life; once living and now decaying/decomposing materials.
   B. **Radioactive decaying matter and transmutational matter** - the change of one element into another as a result of changes within the nucleus.
8. **Programmable matter** - matter with the ability to change its physical properties (shape, density, moduli, conductivity, optical properties, etc.).

1.5 Characterization of materials

Generally, materials are characterized (compared) according to:

1. **Composition** - Composition tells what chemicals are in a sample. The most specific description will reveal the chemical elements that are present in the sample.
2. **Structure** - The three dimensional arrangement of atoms in a sample creates its structure.
   A. **Shape** (object).
   B. **Surface geometry** (surface physics and chemistry).
3. **Properties (physical and chemical)** - Properties are the observed characteristics of a sample.
   A. **Physical properties** - include how a material responds to mechanical forces, heat, and light, displacement, or a combination (e.g., density = mass / volume).
   B. **Chemical properties** - These describe what chemical reactions are likely to occur.
4. **Performance** - The performance of a material is discussed in the context of an application.
5. **Processing and synthesis** - Various methods can be used to create materials from existing substances. For example, processing a material could be as simple as hammering a piece of copper, or flaking arrowheads from a piece

of flint. Synthesis implies a major change in chemical composition; for example, polymers are synthesized by cooking mixtures of chemicals, whereupon new molecular structures result.

These categories are useful ways to understand and sort different materials.

1.6 Material data sheets (MDS)

A.k.a., Object data sheets, mechanism data sheets, process data sheets, etc.

A data sheet provides relevant and useful data on a material system. Every technological system has an accompanying data sheet(s). Data sheet types include, but may not be limited to:

1. **Technical specification sheets (a.k.a., spec sheet, data sheet, data-sheet)** - A data sheet, data-sheet, or spec sheet is a document that summarizes the performance and other characteristics of a product, machine, component (e.g., an electronic component), material, subsystem (e.g., a power supply), or software in sufficient detail that allows a buyer to understand what the product is and a design engineer to understand the role of the component in the overall system.
   A. Product specification sheet
   B. Equipment specification sheet (a.k.a., equipment data sheet)
2. **Safety data sheets (SDS)** - documents chemical hazard information.
   - A **Chemical Abstracts Service (CAS) Registry Number** is a unique identifier for every chemical known to exist.

   A. **Material safety data sheet (MSDS)**
   B. **Hazardous materials data sheet (HMDS)**
   C. **Product safety data sheet (PSDS)**
   D. **Health product declaration (HPD) sheet**
3. **Testing data sheets (TDS)** - a document that identifies the tests and their results conducted on a part of assembly.
4. **Warranty data sheets (WDS)** - a document that identifies all warranty information provided by a manufacturer for a product.
5. **Operations sheet (OS)** - a document that lists all details of the operations needed to complete a part or assembly.
6. **Method specifications sheet** - document material selection and the construction operation process to be followed in providing construction materials and practices. Method specifications provide specifications for the final desired structure and/or mechanism (e.g., concrete thickness and strength, or the lumber dimensions, spacing, species, etc.).

1.7 Chemical abstract service (CAS) registry number

A.k.a., CAS RN, CAS number.

A CAS registry number is a unique numerical identifier assigned by the Chemical Abstracts Service (CAS) to every chemical substance described in the open scientific literature. The CAS registry is the most authoritative collection of disclosed chemical substance information:

- American Chemical Society: CAS Registry [cas.org]

Each CAS registry number (CAS RN) identifier:

1. Is a unique numeric identifier.
2. Designates only one substance.
3. Has no chemical significance.
4. Provides relevant information about a specific chemical substance.

1.8 Hazardous materials

A.k.a., Hazardous substances.

Hazardous substances are classified as substances that are toxic, very toxic, corrosive, harmful or irritants. Hazardous substances (solids, liquids or gases) exposure to which can have negative affects on the body through contact with the skin, inhalation or ingestion. Exposure to hazardous substances can result in short or long term health effects. Hazardous substances can be found both in fabrication/construction, as well as in and around (i.e., from outgassing or flaking) finished products.

Hazardous substances may include, but are not limited to:

1. Flowers, fruits, vegetables and bulbs, which can cause dermatitis.
2. Working for prolonged periods with water and cleaning agents, which can cause dermatitis.
3. Prolonged contact with wet cement which can lead to chemical burns or dermatitis.
4. Dusty or fumy conditions which can cause lung diseases.
5. Paint, glue, ink, lubricant, detergent and beauty products.
6. Other.

1.8.1 Deleterious materials

The term 'deleterious materials' is a broad one, encompassing not only materials that are dangerous to health or which are the causes of failures in structures, but increasingly, materials which are environmentally damaging. It should be noted however that all materials can be considered deleterious under the wrong circumstances (for example, water can be very damaging and can cause extensive pollution). The list of deleterious materials has always remained fluid because as technology advances new products come onto the market and medical research establishes new risks to health.

1.8.2 Irritant material handling

When irritant materials are discovered near human occupancy, they are handled in the following way:

1. Identify material.
2. Isolate material.
3. Remove material safely.

1.8.3 Material pollution

Materials become pollutants when they are positioned in undesirable locations. Therein, metabolites can remain in the environment for decades longer than their parent compounds and are sometimes even toxic and biologically altering than their parent.

2 Solid material types

Traditionally, there are three basic material types (i.e., classes of materials) are:

1. Metals (a.k.a., minerals)
2. Stones (a.k.a., rocks and minerals).
3. Ceramics (a.k.a., "advanced stone")
4. Polymers.
5. Composites.

In material science, it is more appropriate to classify materials according to their properties, but also their usages (*See below*).

2.1 Stone

A.k.a., Rock.

Stone is a type of crafting material and can be used for many different purposes. Although seldom used to form entire structures, stone is greatly valued for its aesthetic appeal, durability, and ease of maintenance. The most popular types of stone include: alabaster, basalt, granite, onyx, quartzite, limestone, travertine, sandstone, marble, slate, gneiss, and serpentine. Stone that is used for structural support, curtain walls, veneer, floor tiles, roofing, or strictly ornamental purposes is called building stone. Building stone that has been cut and finished for predetermined uses in building construction and monuments is known as dimension stone.

2.1.1 Hazards of stone

Designers must be careful about the position of some stone material. For example, marble is terrible for countertops, because anything acid will eat into it and other chemicals will stain it.

2.2 Biomaterials

A biomaterial is any substance that has been engineered to interact with biological systems. Biomaterials are any synthetic or natural material used to improve or replace functionality in biological systems. Biomaterials are employed in components implanted into the human body for replacement of diseased or damaged body parts. These materials must not produce toxic substances and must be compatible with body tissues (i.e., must not cause adverse biological reactions). In other words, biomaterials are biocompatible and work synergistically with the biological host.

2.3 Bioelectronic materials

Bioelectronic use conductive polymers, organic semiconductors, carbon nanotubes, graphene, gold nanoparticles, photonic dyes, quantum dots, and microfluidic materials for applications in biosensing, bioimaging, wearable electronics, and implantable electronics.

2.4 Ceramics and oxide materials

Ceramics are inorganic non-metallic materials whose formation is due to the action of heat. A ceramic is any of the various hard, brittle, heat-resistant and corrosion-resistant materials made by shaping and then firing an inorganic, nonmetallic material, such as clay, at a high temperature. A ceramic is a non-metallic material composed of inorganic molecules, normally prepared by heating a powder or slurry. Many common ceramics are made up of oxides or nitride compounds and are highly crystalline with long-range molecular order. Some ceramics are partially or fully amorphous, with no long-range molecular order; these are typically classified as glassy materials.

> **CLARIFICATION:** *Diamond and graphite, which are two different forms of carbon, are considered to be ceramics even though they are not composed of inorganic compounds.*

The six basic ceramic materials are (Note: the first five are classified as traditional ceramics and mainly made from natural raw materials):

1. Glasses (a.k.a., whitewares)
2. Clay products (e.g., brick and tile)
3. Refractories
4. Abrasives
5. Cements
6. Advanced ceramics - ceramics made from artificial or chemically modified raw materials.
   A. Electroceramics
      1. Electronic substrate, package ceramics
      2. Capacitor dielectric, piezoelectric ceramics
      3. Magnetic ceramics
      4. Optical ceramics
      5. Conductive ceramics
   B. Advanced structural ceramics
      1. Nuclear ceramics
      2. Bioceramics
      3. Tribiological (wear-resistant) ceramics
      4. Vehicular ceramics

2.4.1 Glass

Glassy materials are hard, brittle, and noncrystalline. The lack of crystalline grains often results in optical transparency. The glass we are used to is a ceramic usually consisting of a mixture of silicates or sometimes borates or phosphates formed by fusion of silica or of oxides of boron or phosphorus with a flux and a stabilizer into a mass that cools to a rigid condition without crystallization. Glass is generally a mixture of silica sand, soda ash, and limestone. These compounds are heated together into a liquid, molded into shape, and sometimes fabricated into a structure.

In general, appropriately made and pure glass has the following material properties:

1. Nonconductive to electricity.
2. Nonreactive to water
3. Nonreactive to acid
4. Evaporation from molten glass can cause release of particles in the atmosphere.

2.5 Composite materials

Composites are mixtures of two or more bonded materials. Composites are the mixture of multiple materials, which in combination offer superior properties to the materials alone.

Composite materials include, but are not limited to:

1. Metal-ceramic composites
2. Metal-polymer composites
3. Ceramic-polymer composites
4. Concrete is a ceramic composite
5. Natural composites (e.g., wood, which is a composite material made from lignan and cellulose).

2.5.1 Concrete

Concrete is a ceramic composite made up of water, sand, gravel, crushed stone, and cement. The ingredients are mixed together thoroughly, and are poured into a form. After the concrete is completely dry, it has excellent compressive strength.

Concrete has excellent compressive strength, and unreinforced concrete blocks can be stacked miles high before the bottom-most blocks gets crushed. Concrete has little strength under tension. Modern builders work around this problem by making concrete into a composite, by embedding a rebar cage or mesh in a concrete slab, with enough thickness on either side so that when, under load, the armature stretches, the slab bends hardly at all. Because, if it did bend, cracks would instantly open up on the convex side, letting in moisture, causing the rebar to corrode, expand, and cause "spalling" (meaning the concrete structure falls apart). What's more, this is bound to happen eventually in any case, and so reinforced concrete slabs are engineered for eventual failure by being over-reinforced and under-cemented, because then they give warning of impending disaster in the form of cracks, as opposed to failing catastrophically.

Types of concrete include, but are not limited to:

1. Portland cement concrete (traditional 21st century

concrete) - Portland cement is the source of the cement ("glue") that holds most modern concrete together. Making portand cement requires heating a mix of limestone and clays to 1,450C.
2. Ancient Roman concrete - Portland cement with a lyme and volcanic ash mixture. Portland cement is the modern type of cement. In seawater portland cement has a lifespan of ~50 years after which it corrodes. Ancient Roman cement lasts longer. The Romans perfected a mixture that used much less lime than portland cement and cemented at 900C or lower. The Romans mixed lime and volcanic rock for regular concrete structures, while underwater structures were made with lime and volcanic ash that formed a mortar. When this mix connected with seawater, a hot chemical reaction occurred that cemented the lime and ash mixture. The secret ingredient is aluminum-rich pozzolan ash and it turns out that oil-producing Saudi Arabia has a lot of it.
3. Aircrete - aircrete is made from a mix containing cement, lime and pulverised fuel ash (PFA) and a dash of aluminium powder. Aircrete is a material that combines the strength and durability of concrete which is physically light weight that helps make a home easy and fast to construct.
4. Cococrete/coco-peat - Cement and coconut fiber and lime and sand - a soft concrete that will start to moss up a bit when it gets wet, gives an ancient ruin look.
5. Bioconcrete - Concrete that heals itself using bacteria. The bioconcrete is mixed just like regular concrete, but with an extra ingredient -- the "healing agent." It remains intact during mixing, only dissolving and becoming active if the concrete cracks and water gets in. Tziviloglou et al., (2017) chose calcium lactate, setting the bacteria and calcium lactate into capsules made from biodegradable plastic and adding the capsules to the wet concrete mix.

2.5.2 Wood

Wood is a composite material made from lignin and cellulose. Wood makes use of a lignin matrix and cellulose fibers to form a polymer composite. The lignin holds the cellulose compressively in place so that the cellulose fibers can carry tensile loads. Wood has excellent structural properties, in light of its low weight and high strength.

2.6 Ceramic polymer

Ceramic with an inorganic polymer. So, it has the properties of a polymer in that it forms molecular bonds with metal and wood and themselves, as well as the properties of a ceramic in that they are highly crystalline (covalent and ionic bonding), and the properties of a cement such that it can be made into a powder and doesn't require high heat. Different aggregates can be added to the ceramics to make different qualities of building materials. If there is projectile damage, then ceramic can be mixed on site to patch damage. And, the ceramic can be sprayed to resurface the whole object.

2.6.1 Bioceramic polymer

Bioceramic are also known as chemically-bonded ceramics. Bioceramic is a chemically-bonded ceramic that forms strong molecular bonds like a polymer. Bioceramics can be chemically bonded with many different types of materials. Crucially, bioceramic has the same property that makes cement so useful: the ability to mix it into a slurry and pour it into a mold without using high heat. Bioceramic can be a highly environmentally friendly material. It can be easy to manufacture, and can be designed to be much stronger than concrete.

Bioceramic is fireproof, doesn't decompose readily when exposed to the elements (i.e., doesn't mold, doesn't rot, doesn't rust). Bioceramic can be made via carbon neutral processes. Bioceramic can be powderized before usage. Bioceramic can be used and built into multiple shapes.

Phosphate bioceramic polymers are some of the most usable and easy to work with bioceramic polymers.

2.7 Electronic / Optical

Electronic/optical materials are designed to conduct electricity or light. These materials may be metals, ceramics or polymers. These materials are carefully formulated to control the intensity, scattering, and bending of electrons or photons which pass through them.

2.8 Graphene materials

A.k.a., Carbon fiber.

Graphene is a polymer, an allotrope of pure carbon comprised of a single layer of atoms.

2.9 Metals, alloys, and magnetic materials

Metals are elemental substances that readily give up electrons to form metallic bonds and conduct electricity. Almost all metals have an orderly arrangement of atoms, resulting in a crystalline structure that may have multiple crystal phases bordering each other.

Some of the important basic properties of metals are:

1. Metals are usually good electrical and thermal conductors.
2. At ordinary temperature metals are usually solid.

3. To some extent metals are malleable and ductile.
4. The freshly cut surfaces of metals are lustrous.
5. When struck metal produce typical sound.
6. Most of the metals form alloys. When two or more pure metals are melted together to form a new metal whose properties are quite different from those of original metals, it is called an alloy.

Metals may be magnetic or non-magnetic. The magnetic properties of metallic materials are due to:

1. The atoms of which these metallic materials are composed.
2. The way in which these atoms are arranged in the space lattice.

Metallic materials are typically classified according to their use in engineering as under:

1. **Pure metals** - consist of a single element. Samples of these metals contain nothing but atoms of a single metallic substance.
2. **Alloys** - contain two or more elements or alloys melted and blended together, so their chemical formulas consist of more than one element.

2.9.1 Metal alloys

A.k.a., metallic alloys.

Metal alloys are classified as either ferrous or non-ferrous:

1. **Ferrous** - the group which contains mainly iron (Fe).
    A. Cast iron
    B. Steels
        1. Low alloy
        2. High alloy
2. **Non-ferrous** - other metallic materials containing no iron.

2.9.2 Metallurgy

A.k.a., Metallurgical science.

Metallurgy is the branch of science and technology concerned with the properties of metals and their production and purification. In other words, metallurgy, as a branch of engineering, is concerned with the production of metals and alloys, their adaptation to use, and their performance in service

Metallurgical science involves:

1. Physical metallurgy - the science of making useful products out of metals.
2. Process metallurgy (a.k.a., extraction metallurgy) - the practice of removing metals from an ore and refining the extracted raw metals into a purer form.

2.10 Metamaterials

A metamaterial (from the Greek word μετά meta, meaning "beyond" and the Latin word material, meaning "matter" or "material") is a material engineered to have a property that is not found in naturally occurring materials. Metamaterials are composite systems whose properties are dominated not by the individual atoms, but by the properties of larger, artificially produced structures or "meta-atoms." The concept of "meta" comes from the ability to engineer artificial materials, consisting of a composite of nanoscale structures, which can respond to other materials and to light in entirely new ways. A metamaterial is an engineered material specifically designed to exhibit a behavior that can only occur at specific organizations and sizes of materials. Metamaterials often seem to break the rules of physical behavior. In other words, metamaterials are composite media that can be engineered to exhibit unique electromagnetic properties. Simply, the field of metamaterials involves designing complicated, composite structures, some of which can manipulate electromagnetic waves in ways that are impossible in naturally occurring materials. Metamaterials are usually arranged in repeating patterns, at scales that are smaller than the wavelengths of the phenomena they influence.

Metamaterials derive their properties not from the properties of the base materials, but from their newly designed structures. Their precise shape, geometry, size, orientation, and arrangement gives them their new properties.

Metamaterials have even been shown to be capable of solving integral equations by encoding parameters into the properties of an incoming electromagnetic wave through a material structure that manipulates the wave in such a way that it exits encoded with the solution to a pre-set integral equation for that arbitrary input (Estakhri, 2019).

2.11 Nanomaterials

A.k.a., Nano-structured materials.

Nanomaterials, synthesized from both organic and inorganic materials, are defined as the functional [solid] materials with size below 100-nm in length along at least one dimension (Zhong, 2009). In other words, nano-structured materials are defined as solids having microstructural features in the range of 1–100 nm (nano = (1-100) × 10^{-9} m) in at least in one dimension. This includes both nano-objects, which are discrete pieces of material, and nanostructured materials, which have internal or surface structure on the nanoscale; a nanomaterial may be a member of both these categories.

2.12 Polymer materials

A.k.a., Plastics.

The term "polymer" is often used to describe plastics and other materials. Literally translated, polymer means "many units." These units are sometimes referred to as monomers, and they are the building blocks that form a plastic. Plastics/polymers are made up of millions of repeated links to make long molecules or networks that are tangled or crosslinked together. Almost all polymers use carbon atoms in very long chains. The carbon atoms may be attached to other carbon, oxygen, nitrogen, and hydrogen atoms. Polymers may or may not have an orderly arrangement of atoms. To form a plastic article, these monomers undergo a chemical change that causes them to become connected to each other. In addition to synthetic plastics, the term "polymer" also can be applied to natural biopolymers.

There are three basic types of polymers:

1. **Natural polymers** - polymers found in nature that have not undergone any chemical modification by humans.
2. **Biopolymers (a.k.a., natural biopolymers)** - natural polymers that have been chemically modified.
3. **Synthetic polymers (a.k.a., synthetic plastics)** - polymers that have been made entirely by humans.

Together, there are nine natural polymers and biopolymers:

1. Adhesion Proteins
2. Carbohydrates and Starches
3. Cellulose
4. Chitosan and Chitin
5. Dextrans
6. Gelatin
7. High-purity Collagen
8. Lignins
9. Polyamino Acids

Natural polymers tend to be readily biodegradable, although the rate of degradation is generally inversely proportional to the extent of chemical modification.

The polymer types by usage category include:

1. Biodegradable polymers
2. Block copolymers
3. Π-conjugated polymers
4. Dendrimers
5. Engineering polymers
6. Hydrophilic polymers
7. Hydrophobic polymers
8. Natural polymers and biopolymers
9. Poly(ethylene glycol) and poly(ethylene oxide)
10. Polymers for membranes
11. Polymer standards
12. Silicones

2.12.1 Plastic resin identification codes

Plastic resin identification codes are printed most plastic products. The identification codes always have a number, and which may sometimes be encircled by three arrows. In the case of the resin identification codes, the arrows in the shape of a recycling symbol mean nothing. The number in the middle of the arrows (if present) represents the kind of plastic the object was made from. The arrows were added for manipulation, in order to mimic the recycling symbol. The first two codes (1-PETE and 2-HDPE) are recyclable. The next four (3-6) require special equipment to recycle. The other resins are not recyclable.

2.12.2 Shape memory polymers

A shape memory polymer is a special material that has the ability to be deformed and held into a temporary shape and then return to and remember it's original shape. These polymers can be 4d printed; wherein, the fourth dimension allows for shape change over time.

2.13 Semiconductor materials

Semiconductors are a special case of electronic material that combines two differently electrically conductive materials, usually ceramics. A semiconductor is also known as a P-N junction, where one material allows 'loose' electrons to move through an ordered structure, and the other allows holes (where an electron could be, but is not) to move in the same way. This behavior and the interactions between charge carriers and photons and phonons allows semiconductors to store binary information, form logic gates, and convert between voltage, light, heat, and force as sensors and emitters.

2.14 Textile materials

A textile is a flexible material consisting of a network of natural or artificial fibers (i.e., yarn or thread). Technically, a textile is an inhomogeneous porous medium. Yarn is produced by spinning raw fibres of materials to produce long strands. Textiles are formed by the following types of processes: weaving, knitting, crocheting, knotting, tatting, felting, braiding, etc.

2.14.1 Smart textiles

Smart textiles can be defined as textiles that are able to sense and respond to changes in their environment. They may be divided into two classes: passive and active smart textiles. Smart textiles can monitor an environment and be programmed to react in particular ways. (Koncar, 2016)

2.14.2 Classification of textile fibers

Classification of textile fibers includes, but is not limited to:

1. **Natural fiber**
   A. **Animal (protein derived)**
      1. Silk (from sericteries)
      2. Animal hair (from hair bulb)
         i. Alpaco
         ii. Cashmere
         iii. Camel
         iv. Feather
         v. Goat
         vi. Horse
         vii. Human
         viii. Wool (note: a highly renewable/ sustainable material given the presence of sheep).
   B. **Mineral**
      1. Asbestos
         i. Amosite
         ii. Crocidolite
         iii. Tremolite
         iv. Actinolite
         v. Anthophyllite
         vi. Chrysotile
   C. **Plant (cellulose/lignocellulose derived)**
      1. Seed fibers
         i. Cotton
         ii. Kapok
         iii. Loofah
         iv. Milk weed
      2. Bast fibers - Bast fibre (also called phloem fibre or skin fibre) is plant fibre collected from the phloem (the “inner bark”, sometimes called “skin”) or bast surrounding the stem of certain dicotyledonous plants.
         i. Jute
         ii. Flax (linen)
         iii. Hemp
         iv. Kenaf
         v. Kudzu
         vi. Mesta
         vii. Okra
         viii. Rattan
         ix. Ramie
         x. Rosella
         xi. Wisteria
      3. Leaf fibers
         i. Abaca
         ii. Agave
         iii. Banana
         iv. Fique
         v. Henequen
         vi. Manila
         vii. Raphia
         viii. Sansevieria cylindrica
         ix. Sansevieria ehrenbergii
         x. Sansevieria trifasciata
         xi. Sansevieria stuckyi
         xii. Sansevieria kirkii
         xiii. Sansevieria pinguicula
         xiv. Sisal
      4. Fruit
         i. Coir
         ii. Oil palm
      5. Wood
         i. Soft wood
         ii. Hard wood
      6. Stalk
         i. Rice
         ii. Wheat
         iii. Barley
         iv. Maize
         v. Oat
         vi. Rye
      7. Grass/reeds
         i. Bamboo
         ii. Bagasse
         iii. Corn
         iv. Sabai
         v. Rape
         vi. Esparto
         vii. Canary
2. **Human made (Manufactured)**
   A. **Natural polymer (artificial, regenerated)**
      1. Alzon (protein derived)
      2. Chitosan (natural sugars derived)
      3. Cupro
      4. Rayon (viscose/cuprammonium; cellulose derived)
      5. Modal
      6. Polynosic
      7. Deacetylated acetate (cellulose derived)
      8. Acetate (secondary triacetate; cellulose derived)
      9. Alginic (alginate)
      10. PLA (natural sugars derived)
      11. Lyocell (cellulose derived)
      12. Elastodiene
      13. Tencel
      14. Rubber (natural)
   B. **Synthetic organic (synthetic polymer)**
      1. Acrylic, polyvinyl
      2. Anidex
      3. Aramid/kevlar
      4. Carbon fiber
      5. Chlorofibre
      6. Elastin (elastoester)

7. Fluoro fibre (fluoropolymer, teflon)
8. Lastrile
9. Melamine
10. Modacrylic
11. Novoloid
12. Nitrile
13. Polyamide (nylon)
14. Polyester (aromatic polyester)
15. Polyethylene
16. Polypropylene
17. Polyurethane
18. Polyolefin (olefin)
19. Rubber (synthetic)
20. Saran
21. Spandex
22. Sulfur
23. Trivinyl (vinyl)
24. Vinyon

C. **Inorganic**

1. Metallic fiber
2. Glass fiber
3. Boron fiber
4. Silica carbide

3 Gas material types

There are many types of gas, including combinations of different elemental gases. Some gases can, and others cannot, be safely compressed. A gas has molecules that are very far apart from each other, whereas a solid or liquid has molecules that are very close together.

Some of the more commonly used gases in a habitat service system are:

1. Air is necessary for humans to breath. Air has various qualities and various elements, all of which must be within human parameters for humans to survive. Air is composed of oxygen, nitrogen, argon, carbon dioxide, and traces of several other gases.
2. Pure oxygen (O_3) is useful for medical and construction purposes.
3. Medical gases are specific gases used in various medical procedures and medical technologies.
4. Industrial usage and waste gases.
5. Ozone (O_3) is useful for disinfecting and eliminating unwanted bacteria and other potential pathogens. The machines used for disinfecting are not medical grade ozone generators. Firstly, they use ambient air (and not pure oxygen), and secondly, they use equipment that generally is not highly ozone resistant, so there will be some breakdown of materials.
6. Propane, methane, and butane are useful for combustion purposes.
7. Refrigeration gases, including but not limited to: HFC-134a (1,1,1,2-Tetrafluoroethane), R134A Tetrafluoroethane, R438A Freon, R600A Iso Butane, and historically, R22 Chlorofluorocarbons.
8. Carbon dioxide (CO_2) is useful for growing many plants indoors.
9. Carbon monoxide (CO_2) is a common waste gas from combustion of other gases.
10. Vapor, primarily water vapor, is useful for many purposes including electricity generation and/or heating.

NOTE: *There are many toxic gases. Gas that in low concentrations may not be harmful can be harmful in higher concentrations.*

3.1 Compositions of gas

There are three primary categories of gas depending upon their atomic composition:

In this way, gases can be classified as:

1. Elemental gases: Certain elements exist as gases

at standard temperature and pressure. When the pressure is changed and is higher or lower, or when the temperature is changed and is higher or lower, the element may exist in a different form such as in liquid form or solid form. Elements will become gas at different temperatures.

2. Pure gases
    A. Made up of individual atoms.
        1. Classified based on reactivity, there are noble gases, which are the least reactive of all known elements.
    B. Atomic gases:
        1. Monoatomic gases (1 atom molecules) - gases of only one atomic element. All the individual elements [in the periodic chart of elements].
        2. Diatomic gases (2 atoms molecules) - gases of only two atomic elements. Some diatomic molecules have single bonds (shared electron pairs), others have two or three. Not all atom species form diatomic molecules. Elements that exist in diatomic molecules (a molecule containing two atoms of the same element or species), include:
            i. Oxygen (O_2)
            ii. Hydrogen (H_2)
            iii. Nitrogen (N_2)
            iv. Flourine (F_2)
            v. Chlorine (Cl_2)
            vi. Bromine (Br_2)
            vii. Iodine (I_2)
        3. Triatomic gases (3 atoms in molecules) - gases of only three atomic elements.
        4. Polyatomic gases (4 or more atoms in molecules) - gases of more than three or more atomic elements. Air is the most common polyatomic gas on the plant. For example,
            i. Phosphorus (P_4)
            ii. Sulfur (S_8)
            iii. Ammonium (NH_4)
3. Mixed gases - A mixture is two or more gases. For example,
    1. Acetylene (C_2H_2)

3.2 Sensing gas

Instruments can be made to detect gases, and their concentrations.

4 Oil material types

There are many types of oil, including combinations of different oils. Some oils can, and others cannot, be safely compressed.

Some of the more commonly used oils in a habitat service system are:

1. Edible oils.
2. Petroleum hydrocarbon oils.
3. Solvent oils.
4. Lubricating oils.
5. Industrial usage and waste oils.

> **NOTE:** *There are many toxic/poisonous oils. Oils that in low concentrations may not be harmful can be harmful in higher concentrations.*

4.1 Sensing oils

Instruments can be made to detect oils, and their concentrations.

5 Liquid material types

There are many types of liquid, including combinations of different liquids. Some liquids can, and others cannot, be safely compressed. Some of the more commonly used liquids in a habitat service system are:

1. Water.
2. Edible liquids.
3. Gasoline (petrol).
4. Cleaning liquids.
   A. Chlorine liquid is used in cleaning, most commonly in textiles and water.
   B. Liquid soaps.
5. Solvent liquids.
6. Lubricating liquids.
7. Industrial usage and waste liquids.

NOTE: *There are many toxic/poisonous liquids. Liquids that in low concentrations may not be harmful can be harmful in higher concentrations.*

5.1 Sensing liquids

Instruments can be made to detect liquids, and their concentrations.

6 Material flows

A.k.a., Matter flows.

Material resource flows refers to the flow of matter/ materials within the physical (a.k.a., material) environment. Where resources are accounted for all identifying notations are tracked and calculated.

Important terminology in concern to materials flow includes:

- **Geology** - the study of how matter deforms and flows, including its elasticity, plasticity and viscosity. In geology, rheology is particularly important in studies of moving ice, water, salt and magma, as well as in studies of deforming rocks.
- **Geodynamics** - the deformation of earth materials.
- **Geomorphology** - that branch of earth science concerned with the shape of terrestrial surfaces.
- **Rheology** - the study of matter when it flows or is deformed.

6.1 Rheology

Rheology is the deformation and flow of matter; measured by a rheometer (or other). Rheology is otherwise defined as the study of flow behavior. Rheology is a well established area of study for a wide range of materials. In other words, rheology is concerned with the time-dependent deformation of bodies under the influence of applied stresses, both the magnitude and rate, whether the bodies be solid, liquid or gaseous.
The term rheology originates from the Greek words 'rheo' translating as 'flow' and 'logia' meaning 'the study of', although as from the definition above, rheology is as much about the deformation of solid-like materials as it is about the flow of liquid-like materials and in particular deals with the behavior of complex viscoelastic materials that show properties of both solids and liquids in response to force, deformation and time. In practical application, rheology is most often applied to fluid materials (or materials that exhibit a time-dependent response to stress). In this sense, a secondary (or sub) definition of rheology is the study of the relationship between force (stress) and deformation (strain) of engineering materials under a set of loading and environmental conditions. (*A Basic Introduction to Rheology*, 2016)

Knowledge of rheological behavior is essential in numerous ceramic processing operations that involve slurries or pastes, including (Moreno, 2001):

1. Beneficiation (e.g., wet mixing and milling, atomization, and filtration).
2. Shape forming (e.g., slip casting-based methods, extrusion, roll forming, injection, and tape casting).
3. Coating/deposition (e.g., enameling, dipping, screening, printing, electrophoretic deposition, and

spraying).

Rheometry is the method used to analyze the rheological behavior of a material. Rheological properties of a material are noted when a force is exerted on it, and as a result of which it deforms or flows. The extent to which a material deforms under a certain force depends strongly on its properties. Therein, rheometry refers to the experimental technique used to determine the rheological properties of materials.

Rheometers are measurement instruments for materials flow used to determine flow properties and viscoelastic properties of a material, the most notable of which is a:

- Rotational rheometer (a.k.a., viscometer) - measures shear flow and viscosity.

7 Materialization

Materialization is the process of acquiring, producing, and using materials.

7.1 Materialization calls

From a materials science perspective, the process of materialization involves the "call" of [factual] information from the following categories:

1. **Resource call:** Materials have properties.
2. **Material call:** Materials may be combined into material compositions to change the expression of [material] properties.
3. **Technology call:** Material compositions may be connected to perform technical functions as a technology module.
4. **System call (a.k.a., Service call):** Material configurations [as technology modules] may be integrated into service through a service system.

7.2 Materials quality control

There are significant differences between quality control in industry and in community. These differences are socio-economic in nature. In industry, the quality control process is as follows: people create things for another group of people; another group of people review and assess the first people's creations. In community, the quality control process is as follows: users openly and collaboratively create things for themselves while interfacing with a unified information model.

In industry, the outputs of processes must constantly be assessed and reviewed due to the presence of significant unknowns (i.e., due to the drive to conceal inputs, processes, and outputs for competitive advantage in the market). In community, the outputs of processes are significantly known due to the presence of a collaboratively developed, unified, and transparent information model. In community, inputs and processes and outputs are available for all to see, and for all to improve. In community, new outputs are tested prior to integration into the service system, whereupon they are tested again. And, once they are operational, we sense and otherwise monitor for signaled changes from the environment as feedback for improving and otherwise adapting (and evolving) our systems (i.e., our inputs, processes, and outputs).

In industry, independent reviews are essential. Competing entities are vying for finite market space, and so, "independent" entities are necessary to check the work of the other competing entities who are behaving for their own advantage. In community, all technical information is open source, and we recognize that we can behave in a way that is to everyone's advantage.

At the systems level, at the level of the Community's unified information model, we can all see and all check each others work. And, we work through our potential, purpose, and play. In industry, people work and compete for “income”. In industry, due to the socio-economic consequences associated with reviews and assessments, they are generally taken as judgments. In community, the evolution of a model is seen as a benefit to all.

8 Biomimicry design

A,k.a., Biophyllic design.

Biomimicry is the study of the function of biological structures. Biomimicry takes design guidance from nature. We are now beginning to remember that other organisms are doing things very similar to what we need to do in ways that have allowed them to live gracefully on this planet for billions of years.

Herein, biophilic design is a concept used to refer to the connectivity of occupants with some form of natural plant environment, generally, through the use of direct nature, indirect nature, and space and place conditions.

9 Material integrity

A.k.a., Material continuity.

Due to the entropic nature of material reality, all material that is formed into an intend functional system has a state of functional integrity (material change impacts function) and non-functional integrity (material change does not impact functionality).

9.1 Surfaces

A.k.a., Geometric surface.

Surfaces need to be carefully selected. Take a painted building for example. Would you rather see the buildup of "dirt" and get rid of it, or use a material that either did not allow for the buildup of dirt and/or did not show the buildup of dirt? Here, dirt is that which has been unintentionally added to or taken away from a surface (i.e., dirt is that which is out of place on a surface). So, dirt could be the buildup of particulate matter on a surface, or it could be deposits from the erosion/corrosion of the surface over time.

A surface has likely been selected because of its various properties. These properties are altered by dirt. Hence, the surface will need to be restored so that it is expressing the original properties desired of it, which may necessitate a [surface] **restoration cycle**.

> **NOTE:** *Losing function is losing the capacity to do something. As a space "wears", its structure can lose its capacity to carry on its function.*

9.2 Product expiration

Product expiration information tells the user that the producer cannot guarantee that the product will function as it is intended after the date (often, an estimation). Naturally, material compounds degrade with environmental exposure to conditions such as light, heat, and temperature. Some products have no expiration. Honey, for example, has would have no expiration date.

9.2.1 Expiration date

An expiration date or expiry date is a previously determined date after which something should no longer be used, or is not expected to function as expected. Expiration date is often abbreviated EXP or ED.

Scholarly references

- Balsubramanian, A. (2017). *Classification of materials*. Technical Report. DOI: 10.13140/RG.2.2.12792.34567 [researchgate.net]
- Estakhri, N.M., Edwards, B., Engheta, N. (2019). *Inverse-designed metastructures that solve equations*. Science, 363(6433), DOI: 10.1126/science.aaw2498
- Meyers, M.A., Chen, P-Y., Lin, A.Y-M., Seki, Y. (2008). *Biological materials: Structure and mechanical properties*. Progress in Materials Science, 53. [meyersgroup.ucsd.edu]
- Moreno, R. (2001). *Rheology*. Encyclopedia of Materials: Science and Technology. pp8192-8196. DOI: 10.1016/B0-08-043152-6/01468-6
- Tziviloglou, E., Wiktor, V., Jonkers, H.M., Schlangen, E. (2017). *Selection of Nutrient Used in Biogenic Healing Agent for Cementitious Materials*. Frontiers in Materials. 4:15. DOI:10.3389/fmats.2017.00015 [frontiersin.org]
- Zhong, W. (2009). *Nanomaterials in fluoresence-based biosensing*. Analytical and Bioanalytical Chemistry, 394, pp47–59.

Book references

- Koncar, V. (2016). *Smart textiles and their applications*. Elsevier.
- S. Karato. (2008). *Deformation of earth materials: an introduction to the rheology of solid earth*. Cambridge University Press.

Online references

- *A Basic Introduction to Rheology*. (2016). Malvern Instruments Worldwide. Whitepaper. [cdn.technologynetworks.com]
- *Types of materials*. Edmonds Community College. Accessed: January 17, 2020. [materialseducation.org]

TABLES

Table 9. Materials > Mechanics*: Major areas/branches of continuum mechanics.*

<table>
<tr><th colspan="4">Major Branches Of Continuum Mechanics</th></tr>
<tr><th>Type</th><th>Sub-Types</th><th colspan="2">Descriptions and studies</th></tr>
<tr><td rowspan="4">Continuum mechanics
The study of the physics of continuous materials</td><td rowspan="2">Solid mechanics
The study of the physics of continuous materials with a defined rest shape.</td><td colspan="2">Elasticity - Describes materials that return to their rest shape after applied stresses are removed.</td></tr>
<tr><td>Plasticity - Describes materials that permanently deform after a sufficient applied stress.</td><td rowspan="2">Rheology - The study of materials with both solid and fluid characteristics.</td></tr>
<tr><td rowspan="2">Fluid mechanics
The study of the physics of continuous materials that deform when subject to a force</td><td>Non-Newtonian fluids do not undergo strain rates proportional to the applied shear stress.</td></tr>
<tr><td colspan="2">Newtonian fluids undergo strain rates proportional to the applied shear stress.</td></tr>
</table>

Measurement Accounting System

Travis A. Grant,

Affiliation contacts: *trvsgrant@gmail.com*

Version Accepted: 8 July 2022

Acceptance Event: *Project coordinator acceptance*

Last Working Integration Point: *Project coordinator integration*

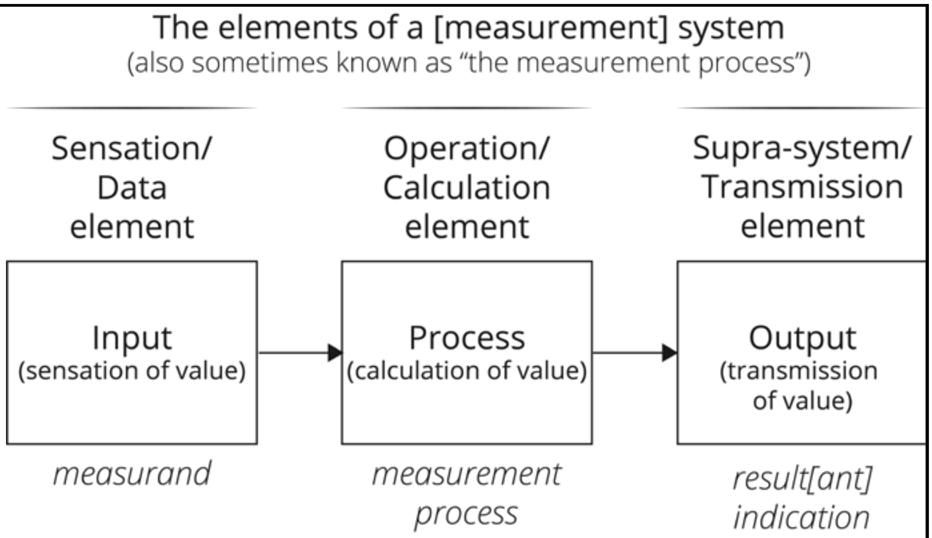
Keywords: measurement system, measurement service, metrological system, metrological service, measurement science, measurement engineering

Abstract

A material system is naturally composed of materials, which are the surfaces of objects. There are different material types, material compositions, material flows, and methods of materializing. To intentionally reconfigure society at the material level, the measurements between the components of which society is composed of at the physical level must be engineered to meet societal requirements. When it is necessary to know the distances between materials (objects, shapes), then measurement becomes significant.

Graphical Abstract

Figure 34. *The elements of a measurement system include sensation of input data, a means of determining alignment to prior sensed and/or prior synthesized values, and means of communicating the result of the alignment determination.*



1 Measurement in physical science and engineering

Science, engineering, and the material aspects of community are built upon measurement. Measurement is fundamental to scientific investigation and engineering. Hence, measurement is the foundation of science and knowledge. How well phenomena are measured affects what we know about them, and rigor in measurement increases the validity of analytical work.

Measurement is the foundation of scientific inquiry. In order to test hypotheses, theoretical concepts must be observed at the operational level. In simple terms, only that which is defined can be measured.

The physical task of designing and constructing an object (a.k.a., something) into the environment relies on measurement. In other words, engineers (i.e., individuals and systems that do these tasks) rely on measurement (and hence, metrology) to accurately design and develop physically functional systems. In order to have safe functioning of a material system it is essential for the systems design remain in some measured degree of alignment with the existent world and the principles of which it is composed.

In part, physics concerns observations, quantified through measurements, and expressed in units. The evolution of understanding around physical units is inevitably intertwined with a growing understanding of physics, the universe, and science itself. For example, after the introduction of the 'Celsius scale' (a concept based on the freezing and boiling points of water), it was only a matter of time before the notion of 'absolute zero' was conceptualized, and the 'Kelvin scale' was established. The Kelvin scale is based on the concept of "absolute zero". At "absolute zero", a hypothetical temperature, all molecular movement stops - all actual temperatures are above absolute zero. The kelvin scale has allowed for the measurement and construction of more complex[ly functional] technologies. Note here that the size of one kelvin degree is the same as the size of one degree Celsius.

Measurements are often associated with control or regulatory mechanisms. Therein, measurement allows for traceability and adaptive feedback. For example, in air-conditioning systems, temperature measurements determine whether heat flows are increased or decreased. In each case, the measurements precede decisions to increase or decrease, or to reject or accept.

All measurements may eventually contribute to a[n optimal] decision.

In order to communicate results unambiguously it is necessary for each of us to share the same scale for a quantity and to have access to the standards that define the scale. For metric scales the traceability problem is relatively simple: all measurements have to be related to a single standard. For the other scale types, the traceability problem can be more complicated because more standards are required.

Measurement is required if actualized (e.g., materialized) systems are to operate safely and remain in alignment with our highest fulfillment.

Ultimately, all measurements are used to help make decisions. Poor quality measurement data will result in inaccurate findings and faulty decisions.

> **APHORISM:** *To control the variable, it is first necessary to measure it. To measure the variable, it is first necessary to define it. To define the variable, it is first necessary to experience it. To experience the variable, it is first necessary to exist in a relationship.*

Measurement is required to validate hypothesis and attain understanding.

> *"When you can measure what you are speaking about, and can express it in numbers, you know something about it; but when you cannot measure it, cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginnings of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be. So therefore, if science is measurement, then without metrology there can be no science." – Lord Kelvin*

1.1 Supra-system measurement objectives

In practice, a supra-system applies measurement for one purpose (that is, environmental information acquisition), and four main objects:

- **Discovery** – by a comparison of something of a presumably known quantity with something similar of an unknown quantity.
- **Diagnosis** – by a timely comparison of the actual quantity value with its normal range.
- **Alarm** – by continuously checking if the quantity value is inside or outside a parameter range.
- **Titration** – finely tuning an adaptive response action to bring a quantity value toward a targeted range.

Each objective type has different requirements, with the final intention off all objectives being to facilitate optimal decisioning, which together with an optimized information model, facilitate optimal living.

A self-organizing system uses the results of measurement to adapt itself to its environment and to improved functioning. The purpose of the measurement system is to link the observer to the phenomenological process (i.e., map/model for the observer the phenomenological process).

The intention of measurement is to acquire more information to inform a more informed and reliable representation of the real world. Wherein, measurement is used for (informs) the orderly and reliable representation of observation (i.e., measurement is the reliable, usable, and practical representation of reality).

1.2 Human decisioning and measurement

Humans desire material fulfillment, which comes [in part] from a specifically ordered approach to informing decisions:

1. **Quality [of material fulfillment]** - In order to generate and sustain fulfillment, it is necessary to take decisions.
2. **Valid decisions** - The optimal decisions cannot be made unless there are good numerical data on which to base those decisions.
3. **Correct numerical data** - Those numerical data, in turn, must come from measurements, which require accuracy [if they are to be useful in deciding optimally].
4. **Calibrated measurement (accurate measurements and calibrated instruments)** - The only way to get "good" numerical data is to make accurate measurements using calibrated instruments.
5. **Traceable standards** - If it is important to compare some [set of] measurements to other measurements made at other places and other times, the instruments must be calibrated using traceable standards.

1.3 The habitat service system measurement operational subsystem

Measurement is a system's process, because its results provide feedback that allow the supra-system to optimize its conditioned functioning. The material measurement system is part of the Community's core information system.

The measurement system integrates into the habitat service system as follows:

1. System: information system core
2. Sub-system: information acquisition and data processing
3. Operations: measurement (measuring), modeling, and calculating
4. Inputs: measurable information
5. Outputs: measurement models > procedures > scales > indications

The associated science and application of measurement is known as, metrology.

Every aspect (entity) of the habitat service system is measured for the optimization of our fulfillment and the well-being of our ecology. Each supra-system and sub-system involves measurement and all operational systems have performance/operational metrics. Therein, there are multiple sub-types of metrics including, but not necessarily limited to: community metrics, project metrics, product/service/process metrics, and quality metrics.

1.4 The function of measurement

Measurement allows for the design, development, and operation of technology. Engineered objects must be designed and developed within fairly narrow limits of tolerance it they are to work at all, particularly if operational systems require interchangeable parts. In this sense, measurement is a [conceptual] device for standardization, by which there is assurance of equivalences among objects.

A second function of measurement, one which shows its scientific importance, is to make possible more subtle discriminations and correspondingly more precise descriptions.

Unambiguously detailed classifications allow for a greater understanding of the principles of reality. Knowing that one thing "depends on" another is of incomparably less scientific worth than being able to say to just what extent changes in the first correspond to changes in the second.

Measurement applies to the process of inquiry in general the ability to verify, predict, and explain. In other words, measurements makes verification, prediction, and explanation possible (i.e., it makes science possible).

> **INSIGHT:** *Measurement is the comprehended awareness of a change from baseline (a reference).*

1.5 International measurement standards

The International Vocabulary of Metrology (VIM, ISO/IEC Guide 99:2007) is the international standards document for metrology terminology, produced by the Bureau International des Poids et Measures. In general, a vocabulary is a "terminological dictionary which contains designations and definitions from one or more specific subject fields" (ISO 1087-1:2000, 3.7.2). The terminological vocabulary in the VIM pertains to metrology, the "science of measurement and its application". It also covers the basic principles governing quantities and units.

The VIM is now in its third edition (as VIM 3). VIM 1 and VIM 2 were mainly conceived by physicists and engineers for measurements in physics and engineering. Chemical measurement was considered to some degree in VIM 2.

The current ISO standards for measurement are:

- The International Vocabulary of Metrology (VIM, ISO/IEC Guide 99:2007)
  - *VIM3: International Vocabulary of Metrology*. (2017). Bureau International de Poids et Mesures. [bipm.org]
- ISO "Guide to the Expression of Uncertainty in

Measurement (GUM)

- *Evaluation of measurement data — Guide to the expression of uncertainty in measurement*. (2008). Bureau International de Poids et Mesures. [bipm.org]

1.6 The international standards definition of measurement

The current definition of measurement (in VIM 3) is:

> *Measurement is a process of experimentally obtaining one or more quantity value(s) that can reasonably be attributed to a [defined] quantity. Therein, measurement is the association of one or more numerical values to existent objects or events.*

Here, there are two principles:

1. Measurement is a process of attribution (to an earlier quantity or procedure).
2. The result of which is one or more quantity values and a measurement uncertainty).

Formerly (VIM 1), measurement was defined as:

> *A quantity subject to measurement. The measurement process is one of determining the value for the quantity.*

Per this definition of measurement there are two principles:

1. A determination process whose ideal outcome pre-exists the measurement itself.
2. The measurand has a single value.

1.7 Measurement sub-defined

Generally speaking, measurement is the process of observing, determining, and recording observations, in order to facilitate understanding and decisioning. That which is recorded by an observer becomes an input into a larger information system that a population uses to adapt. And yet, it is also general parlance for measurement to mean the activity of assigning a number to an observed relationship. Measurement is the assigning of numbers (or words) to empirical objects/events according in some definite organization[al model].

> **NOTE:** *Whereas measurement facilitates understanding [in part] by mathematical-statistical operations, decisioning is facilitated by the application of algorithms optimized for adaptive control.*

Measurement is a determination whose outcome pre-exists the measurement itself. The process determines (as in, "makes known") the value of some [existent] object or event (i.e., "thing") in relation to a pre-existing model of possible [finite or infinite] values, which are logically relatable.

Here, measurement is:

1. An inquiry into a fundamental domain of unitized information in the real [existent] world;
2. The result of which a greater understanding of the real world is programmed;
3. And hence, upon which a more optimized living environment is constructed.

Measurement is the usage of logical information acquisition and determination processes that experimentally interact with a quantity as the property of an entity that expresses some amount of an existence.
Therein, there is an order relation if some expression of a property can be greater or lesser (in quantity) than another. If there is an order relation, then there is a scale. Data with scale properties can be input into statistical operations to derive greater understanding and functionality from the surrounding world.
Measurement is the quantitative comparison between a predefined standard (or procedure) and a measurand to produce a measured result. Measurement is sometimes described (particularly in the social sciences) as the quantification of qualitative observation (of that which may or may not be observed).

Measurement involves 3 principal elements:

1. **The measurand** – quantity whose value is to be measured.
2. **The measurement system** – content, processes, and instruments for comparison.
3. **The observer or control unit** – the supra-system that uses and otherwise performs calculations on the data, and updates the measurement system information and available measurand classifications.

Measurement has two principal inquiry-problem categories:

1. Determining the value of an attribute/property of an entity.
2. Determining the class of entities to which the measurement relates.

1.8 The fundamental forms (types, procedures and operations) of measurement

All measurement takes one of three different fundamental forms (types, procedures and operations) of measurement. At the fundamental, level measurement is composed of the following axiomatic information processes: counting, ordering, and/or sorting. Each of the processes is itself a separate measurement process, although in a measurement system, these processes are generally combined. These processes may otherwise be called the [fundamental] procedures and/or operations of measurement.

The three fundamental forms (process types) of measurement are:

1. **Counting** – identifying [numerical] iterations of a similar [conceptual] pattern. This is by far the most commonly understood referent of the term 'measurement'.
2. **Ordering** – identifying [numerical] positions of a similar [conceptual] pattern. This is the process of arranging iterations into an ordered structure (i.e., arranging in order).
3. **Sorting** – arranging [conceptual and/or numerical] iterations of a similar [conceptual] pattern into categories representing sub-divisions.

These three forms are not just different versions of measurement. They are different fundamental types. The specific properties of each fundamental form of measurement determine:

1. The kinds of mathematical and statistical procedures that can be legitimately applied to a set of measures; and
2. The kinds of conclusions that can be meaningfully drawn from the application of the operations which have been run.

1.9 Characteristics of the conception of 'measurement'

'Measurement' can be viewed from the following perspectives and maintains (to a lesser or greater degree) the following characteristics:

1. **Measurement theory (a.k.a., the mathematical theory of measurement)** is the view that measurement is the mapping of qualitative empirical relations to relations among numbers (or other mathematical entities). The conditions under which relations among numbers (and other mathematical entities) can be used to express relations among objects. In measurement theory, and in mathematics generally, there is a scale of possible, increasingly complex, mathematical operations.
2. **Systems theory** views measurement as the acquisition of information from an environment (including, sub-systems) for adaptive and optimized functioning.
3. **Information theory** views measurement as the gathering, interpretation, interpolation, and integration of information about a system.
4. **Signal theory** views measurement is the reception of a signal from noise and the subsequent mapping of a new iteration to a pre-existing structure for understanding signaled iteration (i.e., sensation).

And, measurement can be viewed as having the following approach-oriented characteristics:

1. **Operational** – measurement is viewed as a set of operations (operational understandings) that shape the meaning and/or evolve the use of a quantity-term in the context of a larger intention.
2. **Empirical** – measurement is viewed as the estimation of mind-independent properties and/or relations.
3. **Analytical** – measurement is viewed as the discovered exploration of empirically operational patterns.
4. **Synthetical** – measurement is viewed as the comparative integration of a standard and a measurand, which produces a result upon which mathematical-statistical operations may be run to integrate new information about an existent [environmental] system.
5. **Model-based** – measurement is the coherent assignment of values to parameters in a theoretical and/or statistical model of a process. When measured parameters are numerical they are called "quantities". Here, measurement proceeds by representing the following interactions with a set of parameters, and assigning values to a subset of those parameters based on the results of the interactions:
   A. An object or event of interest.
   B. An instrument for measurement.
   C. An environment within which the measurement procedure occurs.

1.10 The 'determination' attribute of measurement

Measurement is, in part, a process of determination (or estimation. Measurement involves a determination (and/or estimation). Measurement is [in part] the estimation or determination of extent, dimension, or capacity (of a system), usually in relation to some standard and/or unit of measurement. The result of the process of measurement is the determination of a number of units of the standard (as a real number times a unit).

Among the attributes of measurement (i.e., primary characteristics or principles that compose the concept of measurement), 'evaluation' is one of those primary attributes. Here, evaluation refers to the processes of comparing, determining, and reporting a (counted) numerical value from a quantity-type source of information. The numerical value exists along a continuum of values. Here, previously unknown information is compared (viewed synchronously for pattern recognition) with a pre-existing [measurement] model [of referentially standardized, calibrated objects]. The value which is determined to map ("mirror") with the greatest alignment is then recorded into memory.

During these processes, the following events occur:

1. A numerical value (number) is determined.
2. That value is assigned to the quantity.
3. The number and quantity-type reference point are recorded into a memory.

Whereupon, a computational system (which may or may not be classified as part of the measurement system) initiates mathematical operations (as statistical calculations) on the data to acquire (determine) greater understanding (new information accurate to the accurate uncertainty of the data).

1.11 The 'mapping' attribute of measurement

Measurement is, in part, a mapping process; it is an activity of assigning a number or symbol to an entity in order to characterize a property of the entity according to given rules. In specific, measurement is an empirical to formal comparative mapping process that uses numbers. Measurement presumes that it is possible to preserve an empiric relation (connection with reality), using a numerical relation [known as a magnitude, quantity, or value). Measurement involves the application of 'number' to formally map empirical processes. Here, a number system facilitates real to abstract world transposition.

A number system allows for the empirical representation of real world patterns [of objects and relationships]. Measurement may be viewed as a mapping from the empirical world to the formal, abstract[ed] world. Here, the real world is the domain of the mapping, and the mathematical (or linguistic) world is the range.

For a measurement, there must be a corresponding numerical relation system, with symbols representing the entities and numerical relations corresponding to the empirical relations.

Mapping requires that a relationship shall have been established between the objects and the numbers so that each object there corresponds exactly one number, one point in the abstract space. However, in general, several objects may be mapped on onto the same point.

When the objects are so selected that the rule of assignment permits only one object to be mapped onto any point, then there is a on-to-one correspondence.

> **NOTE:** *The space into which objects are mapped need not consist of numbers. It would be more accurate to say that what is assigned to each object is a numeral rather than a number. The rule of assignment determines certain relationships among the numerals, and it is this pattern of relationships that constitutes the abstract space.*

This type of mapping follows a principle known as the 'representation condition'. The 'representation condition' states that a measurement mapping must map the entities into numbers and empirical relations into numerical relations in such a way that the empirical relations preserve, and are preserved by, the numerical relations. In other words, the relationships which exist between the attributes of objects in the "real world" are preserved in the numbers (or words) assigned these objects in the formal/abstract world.

There are two principal types of mapping processes:

1. Qualification is the mapping of observation to characterization.
2. Quantification is the mapping of observation to number.

1.11.1 Numbering in measurement

> **Insight:** *Numbers can be applied wherever there exists logic.*

Measurement consists of rules (applied logic) for assigning numbers (numbering) to attributes of objects. More specifically, measurement is the [logical] assigning of numbers to empirical events via the application of a set of rules (predefined rules that reference a standard rule). In essence, measurement is possible because of the syntax category (concept) of a 'number'. Numbers express [the presence of] delineation or iteration. In a sense, measurement is [in part] numerical input intended to map the delineation or iteration of observed relationships. In measurement, numerical inputs (numbers) represent a quantity (value or count) of entities in relationship.

In other words, measurement is the assignment of numbers to objects or events in a systematic manner. Or, said another way, measurement consists of rules for assigning numbers to attributes of objects/events. By definition, any set of rules for assigning numbers to attributes of objects is measurement. Measurement of some attribute of a pattern ("set of things") is the process of assigning numbers or other symbols to patterns ("things") in such a way that relationships of the numbers or symbols reflect the [real] relationships of the attribute being measured.

Measurement is the application of a mutually applied semantic system of numerical pattern recognition and categorization used to quantify a property (i.e., attribute, trait, or characteristic) of an existent system. A measurement, itself, takes the form of a number and accompanying unit that connects the number to a meaning, a significant event or concept. The number represents a comparison between the property of the system (or object) being measured, and the same property of a given 'unit of measure'.

Hence, measurement is the assigned estimation or determination of a number as a given 'unit' to a characteristic (property) of an existent object or event (represented as a concept), which can be compared through numbering to other objects or events (i.e., other concepts).

Measurement is the process of systematically assigning numbers to objects and their properties to facilitate the use of mathematics in studying and describing objects and their relationships. Measurement uses numbers to quantify - to process (transform) information into a [type of information known as a] 'quantity', so that mathematical logic may be applied. Numerical input allows for the logic and precision of mathematics (and hence, calculation) to be applied to the study of nature and the design of systems reproducing through its principles. Therein, measurement uses numbers to describe (real world) processes and events.

> **INSIGHT:** *In order to coordinate resource flows in the material (physical) environment for human and ecological fulfillment, the material environment is initially understood to be composed of 'physical quantities', which logically, are quantized in some unit (by an axiomatic conception of existence).*

1.11.2 Mathematical integration and probability in measurement

Here, there is a pattern (variable), which has been separated into a sequence of sub-patterns (sub-set), and there is the probable recognition and integration of that pattern into an adaptive model of the original pattern, which can be described mathematically.

In mathematics, a 'measure' is a function that assigns a non-negative real number (or +(numeral infinity sign)) to (specific) subsets of a set variable (commonly represented as "X", "x", "x", "x", or "y", or possibly any other letter). This variable, the measure[-and], must be countably additive – the measure of a 'large' subset that can be decomposed into a finite (or countably infinite) number of 'smaller' divided subsets, is the sum of the measures of the "smaller" subsets.

> **INSIGHT:** *Variables (e.g., x) are measurable functions, and units (e.g., mass, length) are measurable [real world] functions. There can also exist derived functions (e.g., power).*

In mathematics, the 'additivity' and 'sigma additivity' (a.k.a., 'countable additivity') of a function defined on subsets of a given set are abstractions of the intuitive properties of size (length, area, volume) of a set. Additivity is combinability (as in, the ability to [be] combined). The combing system is called 'add', and the process therein that does the combining (additivity) is called 'adding'.

In mathematical analysis, a 'measure' of a 'set' is a systematic process of assigning a number to each suitable subset of that set, intuitively interpreted as its 'size'. In relationship to visualization, a 'measure' is a combined supra-representation (conceptualization) of the [sub-]concepts of length, area, and volume. Here, parabolic>plane>solid ["Euclidean"] geometry is used to determine suitable subsets of the n-dimensional parabolic>plane>solid ["Euclidean"] space (Rn). Points in Rn are represented in coordinates as x = (x1, ..., xn), where x1, ... , xn are real numbers, and adding subscripts to a point in R n will always represent its coordinates.

There are four operational requirements that must be met for the combining of objects in measurement are:

1. **Commutative** – when two objects are combined the outcome must be the same regardless of which object is taken first.
2. **Associative** – the outcome must be the same regardless of how the combined objects are grouped – that is, the result of combining an object with the combination of two others must be the same as combining with the third the combination of the first two.
3. **Incremental** – the operation must be incremental with respect to the ordering of relation. If two objects are equivalent with respect to that relation, then the combination of either of them with some third object is no longer equivalent to the other one, but precedes it in the order established by the relation.
4. **Equalities** – if the two equivalent objects are each combined with objects equivalent to one another, the outcomes must be equivalent.

> **INSIGHT:** *Our mapping of the underlying nature of reality is not discrete integers, but continuous functions.*

Here, measure theory is the formal model (and its underlying logical understanding) for how mathematics defines integration and probability:

1. **Integration (∫; in operation, ∫(x); a.k.a., function)** – measurable subsets are assigned numbers by [an operational] 'function'. The procedure of calculating an integral is called integration. An integral is a number associated with a function, and is usually called a "definite" integral. A "definite" integral is defined by a de-finiting (boundary or limiting) process. A definite integral is a formal calculation of area beneath a function. Integrals may represent the (signed) area of a region, the accumulated value

of a function changing over time, or the quantity of an item given its density.

A. The modern notation follows from Leibniz's notes, and given a real-valued function and real numbers, the definite integral is written:
   - ∫ab f(x) dx

B. Definite integrals have an indefinite form as well that serves as a partial inverse to differentiation. Just as differentiation measures a function's incremental changes, a definite integral attempts to "un-do" that. Hence, integrals focus on aggregation rather than change.

2. **Probability** – the measure assigned to the whole set is given the value, 1. Therein, measurable subsets are events whose probability is given by the measure. A probability measure is a measure with a total measure of one. A 'probability space' is a measure space with a probability measure. Every probability space gives rise to a measure which takes the value 1 on the whole space (and therefore takes all its values in the unit interval [0, 1]). Such a measure is called a probability measure.
   A. A 'probability' or more precisely 'a finitely additive probability measure' is a nonnegative set function P(·) defined for sets A ∈ B that satisfies the following properties:
      - P(A) ≥ 0 for all A ∈ B, (1.2) P(Ω) = 1 and P(Φ) = 0.

1.12 The common parlance definition of measurement

NOTE: *In a mathematical operation, the input is an operand, and in a measurement operation the input is a measurand. The output of measurement is an operand value.*

In common parlance, measurement is the set of operations having the object of determining the "value" of a "quantity" of some "thing". Therein, the 'measurand' is that which is being measured; it is the quantity being measured. The result of a measurement [operation] is a value attributed to a 'measurand'.

Here, there are three important aspects of measurement not apparent from common parlance "definition" of measurement above that do apply to measurement:

1. In concern to number: The results of measurement need not be numeric: grade L, red, and carbon are all legitimate measurement results in the appropriate context. One of the most valuable aspects of symbolic representation is that the symbols in the models may be used to make predictions. Mathematical models and numeric symbols particularly help to quantify predictions that might otherwise be qualitative (or subjective).
2. In concern to intention - Every measurement has a purpose. This is the distinction between a meaningful measurement and meaningless assignment of numerals. In a great many measurements, especially outside the calibration laboratory, the purpose influences the design and outcome of the measurement. Consequently, measurement results may have meaning only within the context of that purpose. Results used for other purposes or gathered without purpose are potentially dangerous.
3. In concern to decisioning - Decisions are associated with real world consequences, which may be beneficial or not beneficial [to human fulfillment and ecological stability]. This highlights the need to know the uncertainty in a measurement in order to assess its applicable usefulness.

Measurement is the symbolic representation of existence to aid in understanding, adapting, and decisioning. It is the process of symbolically representing, organizing new information according to a pre-existing model (pattern) of information.

Any of the following could be symbolically represented through measurement (Read: including, but not limited to):

1. Concept, state, object, event.
2. Quantity, magnitude, amount, weight, degree, value.
3. Quality, property, attribute, characteristic.
4. Principle, rule, statement, argument, variable.

1.13 Conditions for measurement (measurability)

APHORISM: *Only quantity is measurable.*

Measurability can be understood in a number of different ways. Axiomatically, for any measurement, the characteristic (or property) to be measured is a quantity, in that it is an amount of something. Thus, it may be thought of as the sum of a number of elementary parts, or units, of that something. Here, measurement is equivalent to the counting of such units (with reference to a standard set of those units). From this analogy, it is possible to derive the conditions that must be met in order for measurement to make sense, that is, the conditions for measurability.

The minimal conditions of measurement are:

1. **A system of counting (applied pattern recognition)** - Counting is possible due to the

properties of natural numbers, which undergo an order, based on the relation "greater than or equal to," and may be added to each other. Counting is a way of assigning numbers to objects. The objects being measured are classes, and the individuals are numbered in order to be able to assign a measure to the class that they compose. Counting is a way of determining how many things there are of a certain kind.
2. **Empirical existence (ordered relation of experience as entity)** - Measurement implies the empirical existence of the entity for which some magnitude (count) may be specified. Measurement is not a thought experiment, it is empirical.
3. **Properties of existence (properties)** - What is measured is not an entity (e.g., a table or bird), but an property (the other type of entity) related to it (such as, its length or mass).

In concern to counting, objects can be counted, or ordered with respect to some attribute, does not suffice to enable the measurement of magnitude in such a way that arithmetical operations can be performed on the assigned numbers. Here, it is possible to answer questions of more or less, and even to determine how many objects in the field have a greater or smaller magnitude than some given object.

That which is measurable is:

1. Everything that is experienceable, or can be translated into experience.
2. Everything that is observable, or can be translated into observation.
3. Everything that is sensible, or can be translated into sensation.

Measurement may also be understood from perspective of an adaptive system – a system that uses the result of measurement to adapt its decided functioning. Therein, there exists the:

1. **The ability to measure (operational measurability)** - Operation pre-supposes functional design. Measurement as an operation (or series of operations) pre-supposes, at least:
   A. The method of comparison.
   B. The pattern for comparison.
   C. The procedure and apparatus used for obtaining the comparison must be provable.
   D. There are two operational requirements that must be met for measurement to occur:
      1. The standard (of reference) that is used for comparison must be accurately defined.
      2. There must be a pre-existing understanding (i.e, a model) to compare with that which is being measured.
2. **That which has the ability to be measured (empirical measurability)** - Measurability is an aspect of empirical properties (or, an empirical property), which allows for comparison with other empirical properties in terms of their ratio. The measurability of that which exists may be established by demonstrating ("proving") that:
   A. The characteristic under investigation involves an empirical order relation.
   B. Then, either:
      1. A physical addition operation allows the construction of a reference measurement scale and the performing of measurement by comparison with it.
      2. Or, by finding some physical law that allows the measure to be expressed as a function of other quantities.
3. **Utilization of the measured result (adaptational)** - For measurement to be of use (i.e., for the output to be useful for the larger system),
   A. The supra-system:
      1. There must be adaptive integration of control functionality. The larger system must be able to use the new information to change every aspect of itself and its decisioning.
   B. The measurement system:
      1. Validation must be acquired.
      2. Uncertainty must be accounted for.

Measurability may also be understood from the perspective of magnitude. Having magnitude (quantity) is sufficient for measurability. All quantities (including ordinal quantities) have magnitude. Note here that nominal properties do not have magnitude (and conversely to quantities that form scales, nominal properties cannot). Nominal properties do not have magnitude, and therefore, are not measurable; however, nominal properties are usable in a measurement system.

Finally, measurability can be viewed from two perspectives:

1. That which is conceptually "measurable" is a quality.
2. That which is numerically measurable is a quantity. And, a quantity is either a scalar or a vector.

1.14 Clarification of the term 'measure'

In common parlance, the word '"measurement" is used to refer to the result of a measurement process as indicated by a measuring instrument. In the science of measurement, this result is known as an 'indication', and not a "measurement" or a "measure". It is logical that the term 'measurement' relates to the whole [systems-oriented] process of obtaining a quantity value (indication) through comparison.

Measurement is sometimes defined as the act of determining a measure (quantity or quality) of some thing. Herein, a measure is a single quantitative attribute of an entity – the basic building block for a measurement.

Measurement (verb) is a form of observation-memory (verb), where the result of the observation-memory (verb) is the assignment of a quantity to a thing (the subject being observed). In common parlance, the term measurement may refer to the act of measuring (its verb form) or the result of that act (its noun form).

> **NOTE:** *The output of that which measure does is called an 'indication' (also sometimes called a measure, a measurement, or a signal response).*

To measure is to express as a number (or measure or quantity) an extent aspect or aspects of a physical and/or conceptual system.

A measure is a quantitative indication of the extent, amount, dimension, or size of some attribute of a system, product or process. A 'measure' is a quantity or amount given as a real number. It is the result of a method that involves an inquiry resolution process to determine how much [of something which is quantifiable] there is, or how many there are. A measure is a quantity logically assigned (given) to something (physical or conceptual) that can be quantified. Measurement (measuring and mensuration) is the act or process of assigning numbers to phenomena according to a rule "the measurements were carefully done"; "his mental measuring proved remarkably accurate".

There has long been confusion over the definition and appropriate usage of the term 'measure'. Although measurement is what something does, the term 'measure' has several meanings in common parlance. For this reason, it is generally not used without further qualification. For example, the term measure is often used in the following qualified ways:

1. An instrument of measure – an instrument, a device, a tool for determining measurements.
2. A measuring device - an instrument, a device, or a tool for determining measurements.
3. A unit of measure – a constant quantity that serves as a standard of measurement for some dimension.
4. A method of measure – the steps, stages, or processes taken to determine a measurement.
5. A scale of measure (level of measurement) - a classification that describes the nature of information within the numbers assigned to variables.
6. A particular measure[ment] – the 'indication', result, quantity value, or determined value of a measurement.

Expressions such as, "measuring a table", are not uncommon in parlance, though linguistically incorrect -- it is the [categorical] entity-property 'length' of the [categorical] entity-object 'table' that is being measured, not the 'table' as a category-entity itself.

To measure is to compare in a significant way any component (part) of a situation (system).

Here, complexity is expressed mathematically.

Note: In mathematics, a compound measure is a measure composed of two (or more) other measures (of a different type). A compound measure is based on two component measures (i.e., it is a measure with two integrated compounds; it is a "compound" measure). For example, speed is a compound measure composed of a measure of length (kilometers) and a measure of time (hours). Density is also a compound measure, composed of a measure of mass (grams) and a measure of volume (cubic centimeters). Density refers to how compact a substance is.

1.15 Clarification of the term 'metric'

In common parlance, the term metric has the following different, but related, meanings:

1. In general, metric means the whole conception and process of measurement. Etymologically, according to the Oxford dictionary, the word 'measure' is derived from the Latin word, mētīrī (or Ancient Greek, métron). Hence, the words measure and metric are often used synonymously/interchangeably. Here, the difference between metric and measure is:
    A. A 'measure' (dimension) is a fundamental or unit-specific term.
    B. A 'metric' can be derived from one or more measures (dimensions).
2. Tracking – In measurement, there is the tracking of that which is being measured over time. A 'metric' is a quantitative measure of the degree to which a system, component or process possesses a given attribute. A metric is a quantifiable measure that is used to track and assess the status of a specific process. Metrics are measures that are being tracked. There are two primary categories of tracked metrics:
    A. Performance metrics
    B. Calibration (Diagnostic) metrics
3. Standards – In measurement, there is the standardization of that which has been measured previously in time, for purposes of understanding, experimentation, and optimization. A 'metric' is a standard for comparison and/or reference. There are two primary categories of standard metrics:
    A. Performance standards
    B. Calibration (Diagnostic) standards

Wherever measurement occurs there may be a metric. In practice, metrics are the result of tracking measurements over time.

> **INSIGHT:** *'Normalization' occurs when metrics (moral and numerical) that [are known to] cause suffering, become normal, accepted and opted for by a population.*

In concern to tracking, a metric is a measure or combination of measures for quantitatively assessing, controlling, or improving a process, product, or team. Here, a metric is a standard reportable measure used to assess an operation.

In terms of performance, a metric is the desired and/or intended operating numerical value. A metric is a performance value ("performance measure") to be met by a system's process. New measurements (Read: measurement results) are compared to metrics (selected earlier measurement results, benchmarks). The metrics represent the decided and/or optimal value that the measure[d result] should be. A metric represents an earlier measurement(s) against which later (or newer) measurements will be taken to ensure that the system producing measured signals is operating as objective[ly] and functionally as intended. A metric is a previously defined value that a system, when measured, should express. It represents an earlier measurement used as a reference for later measurements. Here, 'metric' means the "standard" numerical or qualitative value, which should be output as a result of the measurement operation.

For any given project or system, where inputs, processes, and outputs are measured, each may have its own associated metric. For example, the inputs must be of a certain metric type (specification metrics); the processes have performance metrics (functional metrics); and, to the supra-system, the outputs have their own metrics usability metrics.

As a standard, a metric is a point of comparing or evaluating some property or attribute of existence and/or performance. A metric is a referential comparison standard against which some property, attribute, characteristic, or performance is being compared.

> **NOTE:** *In concern to measurement as a mapping process, the measurement mapping and rules are usually, together, called a metric.*

In terms of measurement, the standard to which the measurand is being compared is [called] a metric. For example, imagine the length of a solid object (measurand) being measured along ("against") a ruler. The ruler represents the measurement standard (i.e., the metric). And, that ruler was likely made from an earlier standard [metric]. If the ruler were a one meter standard ruler, then the metric [for measuring the object] would be a one meter standard ruler.

The process of defining new performance metrics involves, in order:

1. Determine entity category.
2. Identify measurement entity.
3. Identify attributes of the entity that are to be measured.
4. Define metrics.
5. This will define "success" or "failure" to meet a performance or other operations objective.

2 Metrology

CLARIFICATION: *Metrology should not be confused with meteorology, which is the science of weather phenomenon.*

In VIM3, metrology is defined as the science of measurement and its application. Metrology includes all theoretical and practical aspects of measurement, including the measurement of uncertainty and any field of application. It is the experimental and theoretical study of [weights and] measurement to ensure an optimized determination of the level of uncertainty in any field of science and technology. In practical terms, metrology ensures calibrated instruments deliver accurate results, and engineered systems operate effectively.

Metrology is an integral part of the theory of epistemology, gnoseology (Read: the study or philosophy of knowledge). Metrology is the study of obtaining accurate quantitative knowledge.

Metrology is the basis for empirical science and engineering. It allows for the generation of knowledge (as ordered information with logical uncertainty) of existence by transferring observational data into formal theory, and expressing them with logic (i.e., mathematical-statistical).

Performing a measurement means comparing an unknown physical, existent quantity (or quality) with a quantity (or quality) of the same type. The quantity of the same type to which the unknown quantity is being compared may be considered by a population as a reference, a standard, quantity. That standard may be expressed as itself, as in the case of a meter length ruler (a tool) for measuring a meter of length, or more complexly expressed as in the case of a magnetic resonance machine (an instrument) for measuring tissue position. A measurement necessarily involves a reference frame and therefore units. In the not so distant past, there were numerous units used to measure the same physical dimension, which caused engineering problems. The first coherent system of units only appeared with the French revolution: the metric system.

Metrology is a Greek language derived term for the science of measurement:

- Metro = measurement
- Logy = science (or, study of)

NOTE: *In its practical application, metrology requires standardization between cooperating individuals, groups, and systems.*

Processes in metrology include:

1. Establishing units of measurement.
2. Developing methods of measurement.
3. Analyzing accuracy.
4. Tracing measurements made in practice to reference standards.

There are two types of metrological study:

1. Scientific metrology refers to the inquiry, organization, and development of a measurement standard, and its revision.
2. Applied metrology refers to the adequate functioning of measurement instruments used in operational and testing processes.

At the base of metrology is the definition, realisation and dissemination of units of measurement. Properties of existence (i.e., an existent [real world] concept) are quantised by assigning a property value (i.e., a geometric numerical signifier, real number) in some multiple of a 'measurement unit'.

2.1 Metrological outputs

Metrological standards are the primary data output of metrological studies. The basic classification of measurement standards are:

1. The definition of a 'unit' type: based on some physical constant or an agreed-upon arbitrary standard. For example, in the case of a physical constant, the measurement of [the concept] temperature may be based on any of the following: absolute zero, the freezing point of water, the freezing point of oxygen, etc.
2. The realisation of the unit: by experimental methods and the scaling into multiples and submultiples, by establishment of primary standards. In some cases, an approximation is used, when the realisation of the units is less precise than other methods of generating a scale of the quantity in question. This is presently the situation for the electrical units in the SI, where voltage and resistance are defined in terms of the ampere, but are used in practice from realisations based on the Josephson effect and the quantised Hall effect.
3. The transfer of unit traceability: from the primary standards to secondary and working standards. This is achieved by calibration.

Standards are objects and/or relationships designated as used by all (i.e., "authoritative") for an acceptable and accepted reason [derived through axiomatic metrological concepts]. Whatever value they possess is useful for comparison to unknowns for the purpose of establishing or confirming an assigned value based on the standard. The design of this comparison process for measurements is metrology. The execution of measurement comparisons for the purpose of establishing the relationship between a standard and some other measuring device is calibration.

The ideal standard is independently reproducible without uncertainty. This is what the creators of the "metre" length standard were attempting to do in the 19th century when they defined a metre as one ten-millionth of the distance from the equator to one of the Earth's poles. It was later learned that the Earth's surface is an unreliable basis for a standard, as the Earth is not spherical and it is constantly changing in shape. But the special alloy metre bars that were created and accepted in that time period standardized international length measurement until the 1950s. Careful calibrations allowed tolerances as small as 10 parts per million to be distributed and reproduced in metrology laboratories worldwide, regardless of whether the rest of the metric system was implemented and in spite of the shortfalls of the metres original basis.

2.2 Metrology standard sub-types

There are three principal metrological standard sub-types in the production hierarchy:

1. **Primary standards**
   - Used for calibrating secondary standards.
   - At the highest level, a primary reference standard is assigned a value by direct comparison with the reference base.
   - International Prototype meter, Imperial Standard yard.
2. **Secondary standards**
   - Comparison for error correction between primary and secondary standards is continuous (or, as continuous as resources allow).
   - Exists as a secondary access control for reference of the primary references.
3. **Tertiary standards**
   - Exists as a tertiary access control for reference of the secondary references.

There are also:

1. **Working standards** – used by operators. Exist similar in design to primary, secondary, and tertiary standards. But, they are more numerous in access, and are made of easier to life-cycle (i.e., "lower grade") materials.
2. **Reference standards** – used for reference purposes.
3. **Calibration standards** – used for calibration of inspection and working standards.
4. **Inspection standards** – used by observing and analyzing (i.e., "inspecting") systems.

2.3 Modern standards for the dimensions of physical quantities

Currently, there are five independent units of measure (internationally recognized):

1. Temperature
2. Interval
3. Linear distance
4. Electrical current
5. Frequency
6. Mass

Any measurement can be based on one or more of these axiomatic units of measure (or, measurement units).

Pseudo-dimensional quantities involve angle (radian) measurement, of which there are two independent types:

1. Plane angle
2. Solid angle

**Note that a 'pseudo-dimension' is a dimension in which all tags are pairwise equivalent.*

Interested parties believe that eventually, standards organizations will define each of the independent units of measure in terms of the other four independent units. Length (metre) and time (second) are already connected this way.

It is probable that, eventually, all dimensional units of measure will be defined in terms of the other four [in] dependent units. Length, a linear distance measured commonly by the metre, and time, a frequency measured commonly by the second, are already connected this way. Linear distance can be measured using the known constant (or close to constant) speed of light, and hence, eliminate the metre bar artifact. And, time is measured by setting a cosmic linear distance as a reference standard.

NOTE: *Lesser known is the relationship between the luminance (candela) and current (ampere). The candela is defined in terms of the watt, which in turn derives from the ampere.*

2.4 The generation and application of metrological standards

In the market-State, the International Bureau of Weights and Measures (BIPM) develops measurement standards and enforces their application. In the United States, the National Institute of Standards and Technology (NIST) plays the dual role of maintaining and furthering metrology in the commercial and scientific fields. Presently, NIST does not enforce measurement accuracy directly. Instead, in the United States, the accuracy and traceability of commercial measurements is enforced per the laws of individual states. Therein, the government controls through regulation and enforcement of commercial measurement, as material sold by any unit of measure.

> **NOTE:** *Commercial metrology is also known as "weights and measures" and is essential to commerce of any kind above the pure barter level. Also note that the exact same term, "commercial metrology", is used to describe commercial calibration laboratories that are not owned by the companies they serve. In a commercial context, the term, "scientific metrology", addresses measurement phenomena not quantified in ordinary commerce. Calibration laboratories that serve scientific metrology are regulated as businesses only.*

In a hierarchy or market, a 'standard measure' (in this context, a measurement standard) is defined as something that is created, set up, and established as the norm by an authority as rule of the measure of quantity, weight, extent, value or quality. In other words, a body of people or systems in authority establish a set of rules for measuring things under their control and/or jurisdiction. However, 'standard measures' in community represent mutually integrated information that determines the resolution of a measurement-type inquiry or process. There is a difference between the market/state perception and the community perception, but the underlying concept that there shall exist a mutually used way to compare existence, remains the same.

In community, the metrology intersystem team resolves the determined "international" standards for measurement for the community, which is used by all community systems and sub-systems.

2.5 Axiomatic metrological conceptions

The axiomatic methodological conceptions in metrology (Read: concepts of or relating to the study of measurement methods) are:

1. **Accuracy** – Degree of exactness with which the final product corresponds to the measurement standard. How close is the observed measure to the actual (or, accepted) value. The measuring instrument/tool is a variable. Accuracy is calculated by the formula: % Error = (measured value – actual value) x 100 / actual value
2. **Requirements for accuracy** – what is needed in order to acquire a set degree of accuracy.
3. **Precision** – Ability to produce a measurement consistently. How finely tuned a measurement is, or how close multiple measurements can be to each other? The measuring instrument/tool is a variable. Precision is determined by the number of relative significant digits.
4. **Reliability** - Consistency of accurate results over consecutive measurements over time.
5. **Calibration** - The transfer of traceability from the primary standards to secondary and working standards is accomplished by calibration.
6. **Response time** – the time a system or functional unit takes to react to a given input.
7. **Traceability** - Ongoing validations that the measurement of the final product conforms to the original standard of measurement, and all calibrations therein are precise. Ongoing validations that the measurement of the final product conforms to the original standard of measurement

> **NOTE:** *Accuracy and precision may be demonstrated by shooting at a target. Accuracy is represented by hitting the center circle (the accepted/actual value). Precision is represented by the tight grouping of shots (they are finely tuned).*

2.6 Methods of measurement

The following are the most common methods of measurement in metrology:

1. **Precision or direct method** - measurements are directly obtained through . For example, micrometers, Vernier instruments, scales, and dial gauges.
2. **Indirect method** – calculation is used to visualize the measurement. For example, weight is length x width x height x density.
3. **Comparative method** – two measured values are compared.
4. **Coincidence method** – measurements coincide with certain lines and signals.
5. **Fundamental method** – measuring a quantity directly in related with the definition of that quantity.
6. **Contact method** – sensor/measuring tip touch the surface area.
7. **Complementary method** – the value of a quantity to be measured is combined with a known value of the same quantity. For example, volume determination by liquid displacement.
8. **Deflection method** – the value to be measured is directly indicated by a deflection of a pointer. For instance, pressure measurement.

2.7 Applied size categories

1. **Nominal size** – is the size of a part specified in the drawing. Note that nominal and basic size are often the same.
2. **Basic size** – is the size of a part to which all limits of variation are determined. Or it is the theoretical

size from which limits of size are derived by the application of allowances and tolerances.

3. **Actual size** – is the actual measured dimension of a part.
4. **Tolerance** – the total amount that a specified dimension is permitted to vary. It is the difference between the maximum and minimum limits for the dimension. A tolerance is the total permissible variation from the specified basic size of the part.
   A. Upper deviation (maximum, max)
   B. Lower deviation (minimum, min)

2.8 Metrological standards of measurement

There are perceptions through which that which is being observed and analyzed (i.e., measured) may be understood. These perceptions represented a scale of how fully the operation of the universe is understood.

1. **Line standard** – a distance, a "meter", is defined as the distance between scribed lines on a bar of metal under certain conditions of 'temperature' and 'support'. The meter, for instance, is the distance between the center portions of two lines engraved on the polished surface of a bar of pure platinum-iridium alloy (90% platinum and 10% iridium).
   - **End standard** – is expressed as the distance between two surfaces; generally, with the usage of a precision measuring mechanism (a measuring instrument). Dimensional tolerance as small as 0.005mm can be obtained. These, are not subject to ocular parallax effect because the instrument resolves the distance.
2. **Wavelength standard** – a "meter" is defined as the study and design of interferometry:
   A. Interferometry is a family of techniques in which waves, usually electromagnetic, are superimposed in order to extract information. It is the study and design of system that can account for and control the vibration of a medium as a rate of induction.
   B. The emitted/inducted wavelength of the cadmium line ($\lambda \approx 644$ nm), led to the definition of the ångström as a secondary unit of length for spectroscopic measurements. The ångström or angstrom is a unit of length equal to 10^{-10} m (one ten-billionth of a metre) or 0.1 nanometre.
   C. Krypton-86 ($\lambda \approx 606$ nm) was selected (in 1960) as the new wavelength standard for the [1] meter distance. Hence, the metre is the length equal to 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels 2p10 and 5d5 of the krypton 86 atom.

2.9 Computational metrology and geometry

Fitting is the computational metrological term for associating ideal geometric forms to a discrete set of points sampled on a computationally manufactured surface.

1. **Datum establishment** – for relative positioning of geometric objects.
2. **Deviation assessment** – how far has a part deviated from its intended idea form?
3. Form tolerances (syntax and semantics)

Fitting is an optimization problem:

- Given a set of points X, fit ideal geometric element(s) Y that minimize an objective function involving distances between X and Y, subject to certain constraints.

The two principal types of fitting are:

1. Continuous optimization (e.g., least squares fitting)
2. Combinatorial optimization (e.g., minimax fitting)

Two popular fits:

1. Least Squares Fit – when the objective function uses L2 norm.
2. Chebyshev Fit – when the objective function uses L_∞ or other norm.

Conversely, the main purpose of filtering is to extract scale dependent information, and no compression of data. Filtering refers to convolution:

1. Convolutions of functions (e.g., Gaussian filters)
2. Convolutions of sets (e.g., envelope filters using Minkowski sums)

3 The measurement [comparison] process

DEFINITION: *The process that measures a quantity is known as a 'measurement procedure'.*

In common parlance, the term 'measurement process' could be used to refer to: (1) the measurement system as a whole, including its inputs and outputs; (2) everything included in 1, and the total conversion process of converting the source of the measurand into something measurable; or, 3) it could be used to refer solely to the measurement systems operational process(es). In other words, the processes which might be present to convert some object into an intended measurable constituent are generally considered to be part of the measurement process itself. In some cases, there may be a particular sampling procedure included in the process. In all cases, measurement results are obtained by performing measurement actions.

As the operational element of a system, the measurement process involves a set of operations having the object[ive] of experimentally determining the value of a [unique input] quantity, for a given attribute/ property of an entity, through observation (and hence, attribution) of its relationship to an earlier quantity. Therein, measurement is the process of assigning to some specific instance (of a quality, categorical property or attribute of existence), a numerical value (quantification) and a referential standard (unit).

NOTE: *A 'characteristic' (unique inherent quality) of a system is called a 'property'.*

Measurement (i.e., the measurement process) involves a series of actions (steps, stages) that take place in a defined manner. Some measurements are a single step, and others have many stages.

The purpose of the measurement process is to acquire new information (as comparative data) on empirical phenomena.

3.1 Conceptual phases of the measurement process

The generalized measurement process may be perceived to have the following conceptual phases:

1. Select an observable/sensible [empirical] event (or object).
    - Define the measurand by defining that which has an existent quality or quantity for which information can be acquired (or collected).
2. Develop a set of mapping rules (i.e., a scheme of principles for assigning numbers).
    - Define a standard comparison model.
3. Apply the mapping rule to each observation of that event.
    - Assign a number to a quality (property or characteristic) of an object or event, which can be compared with other objects or events.

3.1.1 Comparison inputs

INSIGHT: *Measurement is an information acquisition by a process of comparison.*

Measurement is the act[ion] or the result of a quantitative comparison between a predefined standard (procedure and/or model), and an unknown magnitude.

In order to complete the mapping, process a determined comparison must occur between [at least] two comparatively aligning inputs:

1. The measurand (unknown magnitude) - Some "thing" defined to exist from which more information can be acquired (the 'measurand'). The 'measurand' is the thing that is being measured, and for which a value will be determined. The measurand has a single value.
2. The comparative standard - A[n agreed upon] 'standard' method[ological scheme] of reference to determine the [standardized] value of the 'measurand'. The measurement standard (or standard of reference) is the pre-existing referential process and/or configured objects used in the comparison.

The value of the 'measurand' (i.e., the quantity value assigned to the measurand) is determined by its relationship (position and/or alignment) to the 'standard'. In usage, the standard [method or tool] of reference is used by an observer (or other decision processing, comparison resolution system) to assign a [quantity] value to the measurand by comparison with the standard in some pre-defined logical way (i.e., method or process).

3.1.2 Comparison methods

TERMINOLOGY: *A* **reference quantity** *value is a quantity value used as a basis for comparison with values of quantities of the same kind.*

There are two types of methodological comparison, direct comparison and indirect comparison:

1. **Direct comparison method** - Direct comparison with either a primary or a secondary standard. The direct comparison method involves a comparison of a measurand with either a primary or a secondary standard, which has the same physical nature as the measurand.
2. **Indirect comparison method** - Indirect comparison with a standard through the use of a calibrated system. Here, an empirical relation is

established between the measurement actually made and the results that are desired. The indirect comparison method is the main method that is widely used in contemporary measurement and control systems. The indirect method of measurement consists of two stages. The first stage involves converting both the standard and measurand into the type of output parameters that are convenient for further processing. The most common output parameters are electrical signals. The second stage of measurement provides a comparison of the first stage output parameters related to the standard and measurand.

3.1.3 The counting and weighing processes

Mass and weight are understandable as different measurements of objects. The following reasons are provided to identify why weight ought to be measured in grams and refer to gravitational pressure, and mass in number of objects counted.

1. Weight (a.k.a., "relativistic mass") is measured by putting an object on a scale and weighing it against another object. The scale units for weight is grams (kilo-,mega-, etc.). How much pressure is an object causing on a scale. The dynamic question is: Did the object increase pressure against the scale? The weight of a given object is relative to its position in the physical universe relative to other objects; weight varies according to where in the universe the measurement takes place (e.g., a ball will weigh less on the moon than on earth). In this way, grams are a unit of [gravitational] pressure.
2. Mass is a quantity of matter, wherein the observer counts the presence of objects (which gives the units used their label). You don't measure mass, you count units of mass and the mass should be stated in units of object masses. When using mass, units are counted. Mass is not measured by putting an object on a scale. Instead, mass is measured by counting the amount of some scale unit of an object. The dynamic question is: Did the object accumulate more atoms? Units of mass are, for example, measured in what is being counted (note: units of mass are not measured in grams, because that is measure of weight, not mass):
   A. If counting atoms then state the answer in number of atoms.
   B. If counting apples, then use apples.

Note that the scientific community in the early 21st century measures mass in grams.

3.1.4 Standard [of reference]

A [standard of] reference can be a measurement unit, measurement procedure, a reference material, or a combination.

1. **Reference material** – a sufficiently homogeneous and stable material with reference to specified properties, which has been established to be fit for its intended use in measurement or in examination of nominal properties.
2. **Measurement procedure** – a description of a measurement according to one or more measurement principles and to a given measurement method, based on a measurement model and including any calculation to obtain a measurement result. A measurement procedure is usually documented in sufficient detail to enable an operator to perform a measurement.
3. **Measurement unit** – a real scalar quantity, defined and applied, with which any other quantity of the same kind can be compared to express the ratio of the two quantities as a unit.
4. **Combination** – a combination of the standards.

3.2 Entities in a conceptually modeled measure

NOTE: *Different disciplines have different measurement ontologies.*

An entity is a conceptual categorization of information defined by common attributes and constraints at the systems level. The term corresponds to the “Entity” construct as defined in ISO 10303-11.

There are at least two principal types (classifications/categorizations) of entities in measurement [systems]: objects (i.e., events, values, methods) and properties (i.e., attributes and characteristics:

Objects (and events, respondents) - Objects are fundamental blocks of understanding (as in, unitizations of information). Objects are the entities (“building blocks”) that compose a mental model of the world. Every “thing” is an object (as a significant, bounded information patterning set). Objects are, for example, phenomena, bodies, or substances, but also individuals, processes, and organizations. Objects and events are described through constraints

1. **Events** – An sensed or experienced interaction [between two or more differentiated objects].
2. **Methods** - A method is an action that an object can perform. An algorithm is a pre-set method. A method is a formal ordering of constraints.
3. **Numerical values (numbers, a syntactic category)** – A unit of information signifying an ordered rank meaning that expresses the magnitude (amount or quantity) of a fundamental iterating pattern. In measurement a number is not

usually used by itself, but in tandem with some other term, its dimension[al property], which will normally correspond to some Aristotelian category of substance or quality. Numerical values are assigned to properties as the result of measurement. In application, a number is a relation between the concepts of 'magnitude' (amount) and 'unit' (reference).

4. **Properties (and attributes, characteristics)** – A 'property tag' names what is being measured. This is the measured property or attribute, which is organized into a relational system otherwise known as a measurement classification (or taxanomical, ontological) system. Herein, a property is either:
   A. A quality (characteristic or attribute) of an object (or event), or
   B. An aspect of its behavior.

Note that it is sometimes said that attributes are properties of entities. In this sense, there are two principal categories of attributes:

1. Internal attributes (direct measures) are measured directly from the entity.
2. External attributes (indirect measurement) are indirectly measured.

Properties are, for example:

- Length, loudness, and frequency.

The ISO VIM3 states that a 'property' is either a nominal property or a quantity, and a quantity is either an ordinal quantity or a Euclidean quantity for which a unit can be defined. Hence, a property is one of the following:

1. A **nominal property or qualitative property (no magnitude or scale)** - Nominal properties cannot form scales. Expressed by categories (names) in a set. A nominal property is a property of a phenomenon, body, or substance, where the property has no magnitude. A nominal property is a property that cannot be ordered according to magnitude. For example, the sex of a human being cannot be ordered according to magnitude – in normal physiological procreation, two sexes are required (i.e., there is no magnitude between each other, or the top-level category). In some disciplines, the term qualitative analysis is used to describe the examination of nominal properties. Qualitative analysis produces [measurement] data acquired without magnitude. In the previous sentence, the term measurement is crossed out; this is because, it is possible to measure a quantity, whereas obtaining information about a nominal property is not a measurement.
2. A **quantity [property] (measurable property)** - Quantities form scales, continuums. If it is not a nominal type property, then it is a quantity type property. A quantity is any property that has a size (magnitude) that can be evaluated (compared and integrated) through some measurement. 'Quantity' is a specific type of property. Only quantities [of phenomenological objects or events] are technically measurable. Each sub-type of this property has an accompanying application as something called a [quantity] 'scale'. A quantity scale (a.k.a., measurement scale) is an ordered set of values of quantities of a given kind used in [sequential] ranking, according to [the order of] their magnitude. Types of properties (e.g., nominal, ordinal, quantity, cardinal) become scales of quantities (e.g., nominal, ordinal, interval, ratio).
   A. An **ordinal quantity** [property] scale - expressed by ordering of categories in a set.
   B. A **cardinal quantity** [property] scales also known as a Euclidean quantity [property] which must have defined units. Expressed by a number and a measurement unit as part of a system of [existent] quantities. The physical quantities of the universe are cardinal/ Euclidean.

Geometric quantities are paradigmatic of measurable entities. Hence, quantity is an axiom of measurement – quantity grounds the theory of measurement. Because measurement requires quantity, and quantity is (axiomatically) logically numerical, the foundations of measurement can be notated in purely mathematical terms.

> **NOTE:** *The division of the concept of 'quantity' according to 'kind of quantity' is arbitrary to the extent that the unified principles of the universe are not yet known.*

The cardinality and ordinality:

1. Cardinal has to do with cardinality or the magnitude or quantity of things.
2. Ordinal has to do with ordinality or the ordering or ranking of things.
3. Thus, first is an ordinal number. Its cardinal equivalent is one.

3.3 Ordinal quantity (ordinal property)

An **ordinal quantity** is a quantity defined by a conventional measurement procedure, for which a total ordering relation can be established, according to magnitude, with other quantities of the same kind, but for which no algebraic operations among those quantities exist. Ordinal quantities are usually not considered to be part of a system of quantities, because they are related to other quantities through empirical relations only.

Examples of ordinal quantities (in applied scale form) are: Rockwell C hardness scale, Octane number for petroleum, and the strength of an earthquake on a Richter scale. The numbers on these scales are arbitrary and dimensionless.

Ordinal quantities have neither measurement units nor quantity dimensions. Ordinal quantities are arranged according to ordinal quantity scales.

3.3.1 Ordinal quantity scale (ordinal scale)

An ordinal quantity scale (ordinal scale) is a conventional reference scale or a quantity scale, defined by cooperation, on which only comparison of magnitude applies. An ordinal quantity scale may be established by measurements according to a given measurement procedure. Also of note, ordinal quantities are ordered on ordinal quantity scales.

3.4 Combining entities in measurement

Measurement combines the categories of quality and quantity in order to establish the quantity of a particular quality. Quantities are fusions of numbers and property dimensions (in metrology, the latter are called 'quantity dimensions', though there also exist qualified properties).

'Entity value' principle states that no entity can possibly at one and the same time take two specific values of the same property dimension (quantity variable). For example, no material object can simultaneously have two masses, two volumes, two electric charges, etc.

The concept of dimension is axiomatic to [material] existence, representing the class of information about which reality itself is composed. The spatial, material system is conceived to have the following initial dimension: length (x-axis), width (z x-axis), height (y x-axis), and time (technically, "space-time/memory"). Here, a 'dimension' is a "pure" measurement, as opposed to a scale, which is a ratio of measurements (e.g., kilometers per hour or amps per second, versus mass or temperature).

The principal [visualization] tool in measurement is 'scale'. A scale is a visualization tool that precisely enables deduction of a value of a given quantity (magnitude or amount) by knowing its position [on the scale] and the scale's ratio [between one position and the next]. A scale is the standard (reference) and scope (boundary) of measurement (e.g., nominal, ordinal, ratio scale, etc.).

A self-organizing system can encode the concepts of objects and properties (relationships) to form scales (visual expressions with position and ratio information), upon which logical processing (i.e., mathematical operations) may be performed.

Here, the concept of a [measurement] unit provides meaning to the 'scale' by differentiated identification of one categorical unit from other axiomatic or derived units).

For the supra-system, the level of measurement (i.e., scale of measurement, property scale, or variable scale) determines how the data will be interpreted (i.e., what mathematical operations can be performed). Therein, knowing the level of measurement resolves what statistical analysis is appropriate on the values that were assigned [to the variable at that level].

When there is a scale of possibilities, there becomes a need for defining quantifiable measures for the optimal functionality of a system. That optimally functional or desired value, of a measured system, is called a 'metric'.

A scale is required in measurement for a specific value, among a sequence of possible values, to have meaning.

3.5 Measurement scales

Measurement scales are the symbolic representation of possible measurement results. Measurement scales are used to categorize and/or quantify variables so that correct mathematical operations may be applied. Each additional mathematical operation generates a new "scale of" measurement. In general, there are four scales of measurement:

1. There are four scales of measurement commonly used in statistical analysis.
2. There are four types of data commonly used in information processing.
3. There are four types of variables commonly used in quantifying and qualifying.

Those four categories (i.e., scales of measurement) are, in order:

- Nominal, ordinal, interval, and ratio.

The scientifically accepted physical quantity-value scaled units are (Read: the fundamental/base quantity values are):

- ...
- The meter scale – property is length units.
- The kilogram scale – property is mass units.
- The second scale – property is time units.
- ...

3.6 Variables in measurement

> **NOTE:** *Measurement operationalization is the process of developing specific variables that will be used to measure a concept.*

A variable is any entity that can take on different values. In statistics, where variables are actually used, a variable is any characteristics, number, or quantity that can be measured or counted. A variable may also be called a data item.

Further, in statistics, the general property that is being measured through one or another of the three fundamental measurement processes (counting, ordering, sorting) is termed a 'variable'. Any particular measured instance of that property is spoken of as a 'variate'. 'Variate' is a single variable instance.

The term 'variable' implies that the results of the measurement process are capable of varying from one time to another or from one item to another. For instance, the categorical measurement of gender among a mixed group of human subjects will vary from one subject to another between the two possible outcomes, female and male.

A specific variable represents a specific concept with a logical indicator or value. It is a data point that can be counted, ordered, or sorted. Strictly speaking, measurement does not occur on things, or qualities, or properties, but "indicants" of properties.

The opposite of a variable is a constant. A constant does not vary from one time to another or from one item to another. It is an unchanging value that will applied mathematically to a data set.

In measurement, the word remains with a common meaning, but is often used in multiple different contexts. The following are the multiple ways in which the term 'variable' may be applied.

In measurement, a variable is:

1. A [measurable] property (attribute or characteristic) of an object or event (of existence) that can be assigned a number (numerical variable) or a category (categorical variables), and
2. Is expected to change over time (measurement variables).

In measurement, there are two types (categories) of variable [processes]:

1. **Qualitative variables (categorical variables)** - A qualitative variable is one which measurement occurs with categories possessing no meaningful numerical values.
2. **Quantitative variables (measurement variables)** - A quantitative variable is one which measurement occurs with meaningful numerical values.

There are different ways variables can be described according to the ways they can be studied, measured, and presented. In common application, entities become types of variables [in numerical-mathematical scales of operation], whereupon variables are typically classified as either of two types:

1. **Categorical variables (a.k.a., qualitative variables)** - Categorical variables are variables whose levels are distinguished by name only. Properties become categorical variables. Categorical variables have values that describe a 'quality' or 'characteristic' of a data unit, like 'what type' or 'which category'. Categorical variables fall into mutually exclusive (in one category or in another) and exhaustive (include all possible options) categories. Therefore, categorical variables are qualitative variables and tend to be represented by a non-numeric value.
   - Categorical variables may be measured on one "scale": nominal.
2. **Numeric variables (a.k.a., quantitative variables or measurement variables)** - Numerical values become numerical variables. Numerical variables have values designated by numbers that have some meaning relative to one another. Numeric variables have values that describe a measurable quantity as a number, like 'how many' or 'how much'. Therefore numeric variables are quantitative variables.
   - Numerical variables may be measured on three scales: ordinal; interval; and ratio.

Numeric, quantitative measurable variables may be further described as either continuous or discrete:

1. **Continuous variables** – variables that have an infinite (or significantly large) number of possible values. A continuous variable is a numeric variable. Observations can take any value between a certain set of real numbers. The value given to an observation for a continuous variable can include values as small as the instrument of measurement allows. Examples of continuous variables include: height, time, age, and temperature.
2. **Discrete (meristic) variables** – variables that only have whole number values. A discrete variable is a numeric variable. Observations can take a value based on a count from a set of distinct whole values. A discrete variable cannot take the value of a fraction between one value and the next closest value. Examples of discrete variables include the number of registered cars, number of business locations, and number of children in a family, all of which measured as whole units (i.e. 1, 2, 3 objects).

The data collected for a numeric variable are quantitative data.

Categorical, qualitative variables may be further described as:

1. **Nominal variable** - a categorical variable. Observations can take a value that is not able to be organized in a logical sequence. Examples of nominal categorical variables include sex, business type, eye color, religion and brand.
   - **Qualitative-nominal** – qualitative variables

where the categories have no natural ordering.

2. **Ordinal variable** - a categorical variable. Observations can take a value that can be logically ordered or ranked. The categories associated with ordinal variables can be ranked higher or lower than another, but do not necessarily establish a numeric difference between each category. Examples of ordinal categorical variables include academic grades (i.e. A, B, C), clothing size (i.e. small, medium, large, extra large) and attitudes (i.e. strongly agree, agree, disagree, strongly disagree).
   - **Qualitative-ordinal** – qualitative variables where the categories have a natural ordering.
3. **Qualitative-dichotomous** – qualitative variables with two categories.

The data collected for a categorical variable are qualitative data.

> **CLARIFICATION:** *The words "measurement variable" are used here in reference to two related things. First, the term 'measurement variables' refers to all possible variables in measurement (as a concept, quantity and quality variables), and secondly, the term 'measurement variable' refers to only quantitative variables.*

In experimentation and measurement data acquisition, there are two axiomatic (principal or ontological) categories, each with two principal types of variables:

1. **Categorical variables** – a variable that can be placed into categories, but these categories may not have any logical ordering. A categorical variable is a property of an object which can be broken down into different classes or categories.
   A. *[Scale level 1]* **Nominal variables** – classification is made into unordered categories. Nominal variables are expressed as names (such as "female"). Nominal variables classify observations into discrete[ly named] categories.
   B. *[Scale level 2]* **Ordinal variables (ranked variables)** – classification is rank ordered on some characteristic. However, there is no indication of how much greater one instance is than another. These are expressed as positions (such as "third"). Ranked variables, also called ordinal variables, are those for which the individual observations can be put in order from smallest to largest, even though the exact values are unknown.
2. **Measurement variables** (a.k.a., numeric variables or quantitative variables) – a measurement variable is one where numerical values can be assigned and objects or events can be ordered according to those values. Measurement variables are expressed as numbers and a reference (such as 3.7 mm).
   A. *[Scale level 3]* **Interval variables** – values for interval variables have equal intervals between them; however, they lack an absolute zero point.
   B. *[Scale level 4]* **Ratio variables** – values for ratio variables have equal intervals between values, and there is an absolute zero point.

The principal [measurement] variable from which all other variables (except nominal) are derived is 'quantity'. Quantity is the source conception of a 'measurement variable' -- if there is a potential differentiation for that which may be known to exist, then what is the separation?

> **NOTE:** *The mathematical theories underlying statistical tests involving measurement variables assume that the variables are continuous. However, [continuous] statistical tests also work on discrete measurement variables. The only exception is when there is a small number of possible values of a discrete variable, in which the variable may be treated as nominal (instead of, a measurement variable).*

In the application of statistics to measurement variables, there is the possibility of calculating for more than one numeric value for a variable:

1. A measurement variable with only two values should be treated as a nominal variable;
2. A measurement variable with six or more values should be treated as a measurement variable;
3. A measurement variable with three, four, or five values requires complex simulation.

3.6.1 Numeric variable scales

1. **The cardinal number scale and cardinal measurement** - In the cardinal measurement there are two subcategories, ratio scale and interval scale, and all cardinal variables are either continuous or discrete.
   A. **Discrete cardinal variables** – count variables. For example, number of people in a town, family size, number of books, number of heads in 10 tosses of a coin, and so on. Discrete variables can have negative values; for example, if the net change in demand is measured by the difference of arrival of customers the result can be negative or positive. Discrete numerical variables are variables that can take on only whole number values. Discrete numerical variables are typically the result of the counting operation/process (e.g., counting things, events, activities, types).
   B. **Discrete scale of measurement** - Discrete

cardinal variables - Discrete/Integer scale of indivisible units: 1,2,3,4,5,6,...

C. **Continuous cardinal variables** - All these cardinal variables (time, height, weight, distance) are examples of Continuous variables - they are measured in real numbers and they have unit of measurement. Continuous numerical variables are variables that can take on any value whatsoever. They can be whole numbers, or they can be numbers to any number of radix points (e.g., decimal points - fractions of a whole number).

D. **Continuous scale of measurement** - Continuous/ratio[nal]/fraction scale of [in principle] infinitely divisible units: 1.23,2.9120,4.323442,...

2. **Equal interval scale** – equal intervals exist between their successive units of measurement. If a measurement scale possesses this property, then it is possible and meaningful to take two or more measures from that scale and perform the simple arithmetic operations of addition and subtraction.
   - **Ratio scale** – a point is designated as zero, which represents an absolute zero of the quantity that is being measured (e.g., zero length represents the absolute absence of length). Scales of measurement that have both equal intervals and absolute zero points are known as ratio scales.
   - **Non-ratio scale (interval scale)** – a point [on the scale] is either:
   - Not designated as absolute zero of the quantity that is being measured (e.g., kelvin temperature scale).
   - Or, the designation of zero is only an arbitrary point that happens to be called "zero" (e.g., celsius temperature scale).

3.7 Conceptual mapping of the empiric, real world through qualification and quantification

Conceptual mapping of the empiric, real world is carried out through [at least] two processes, qualification and quantification.

Note here that the terms 'qualification' and 'quantification' both end with the suffix "-fication". The suffix-noun "-fication" means - making, producing, or representing. For example, reification means to making something real or physical (such as, making a clay pot). However, the concept 'reification' can also be applied philosophically. For example, an actual 'shadow' is the absence of light, where light is an actual thing. The shadow is not the presence of a thing, but its absence. A shadow cannot be reified; it cannot be experienced and conceived of as a separate object/thing. To make the experience of an absence [of a thing] into a thing itself is bound to cause instability in a societal trajectory toward fulfillment and ecological well-being. It could be said that qualification and quantification depend to a large degree on accurately experiencing, and hence conceiving, of the real world. When absences are turned into qualified things and then quantitatively measured, that data may still have usefulness, but the context in which it was

Human cognition can recognize patterns of quality and quantity in our environment. These patterns are mapped to concepts. In concern to measurement, the supra-mapping conceptions are 'quality' and 'quantity'. Whereas quality represents categories and their ordering, quantity represents the presence of a meaningful number.

The properties, characterizations, and attributes of existence can be categorically described in two ways: qualitatively (through words and linguistics) and quantitatively (through numbers and mathematics).

There are two principal descriptive forms (notations or expressions) of 'measurement', in the most general use of the term:

1. A **qualitative description** is the use of words and linguistics.
2. A **quantitative descriptio**n is the use of numbers and mathematics.

Hence, there are two principal types of measurement:

1. **Qualitative measurement** uses words, representing linguistic, semantic conceptions, to describe [that which is/was existent] in relation to a model (scheme) conceived to pre-exist. Qualitative measurement requires the assigning of a word (concept) capable of functioning under linguistical logic (i.e., in a linguistic system).
2. **Quantitative measurement** uses numbers, representing mathematical conceptions, to describe [that which is/was existent]. Quantitative measurement requires the assigning of a number (value or count) capable of functioning under mathematical logic (i.e., in a mathematical system).

Measurement involves processes that determine the value of a [new] quantity or quality of [some category of] information.

1. **Qualitative information** - involves processes that determine the value of [new] qualitative [information].
2. **Quantitative information** - involves processes that determine the value of a [new] quantity [of information].

In this sense, there are two general types of measurement data (and research):

1. **Qualitative data (qualitative research)** is information about qualities; information that cannot be expressed or processed through numerical conception. Qualitative data involves linguistic characteristics and descriptors that can't be measured, but can be observed subjectively.
2. **Quantitative data (quantitative research)** is information about quantities; that is, information that can be measured and written down with numbers. Quantitative data involves numbers and systems that can be measured objectively. When something [existent] is "measured", then the result is quantitative data. All [numerical] measurement is quantitative data.

And, in measurement experimentation there are two types of variables (Read: a concept, factor, trait, condition, behavior, etc) of an object or system (in the real world) that can exist with differentiation (i.e., in differing amounts or types):

1. **Qualitative variables** - take on values that are names or labels.
2. **Quantitative variables** – take on values that are numeric.

3.8 Mapping process categories

There are two mapping process categories for mapping existence to workable information sets. The two process categories are:

1. **Qualify[ing]** means to characterize by naming an attribute; it means to state any property or characteristic of something. Qualify refers to meeting the terms of eligibility or criteria.
   - There is categorization by descriptive values (categorical values).
2. **Quantify[ing]** means to find, determine, or otherwise calculate the quantity or amount of (something). In application, quantify is describing [some thing] numerically.
   - There is categorization by numbers (numerical values).

Measurement is the process of assigning to some specific instance (of a category of existence), a numerical value (quantification) and/or qualifying condition (qualification). All quantities (quantity values) are actually qualified by [their] units, which represent either a qualifying procedure and/or a qualified definition.

> **NOTE:** *"Qualify" is also defined in common parlance as: to have the necessary skill, knowledge, or other requirements to do a particular process, activity, or to have the qualifications to do something.*

3.9 Quantity defined by standards

ISO 80000-1:2009, 3.1: The International Standards Body defines a 'quantity' as a property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed by means of a number and a reference.

A reference can be:

1. A measurement unit.
2. A measurement procedure.
3. A standardized reference material/tool
4. Or, a combination of these.

Simply, a quantity is a property of a phenomenon, body or substance, to which a number can be assigned with respect to a reference (of which there are four possible reference types).

Quantity is a specific type of property. And, only quantities [of phenomenological objects or events] are technically measurable.

International Vocabulary of Metrology 3rd edition (VIM3): starts with a definition of 'quantity' (def. 1.1) followed (1.2) by one for 'kind-of-quantity'. Two other VIM3 definitions relevant are those of 'quantity dimension' (1.7) and 'quantity value' (1.19).

- 1.1 quantity = property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference.
- 1.2 kind-of-quantity = aspect common to mutually comparable quantities.

> **Insight:** *The first axiom of measurement is quantity, and the second, uncertainty.*

VIM3 then defines quantity value as an expression that is related to a spatio-temporally localized (individual) quantity (i.e., a quantity value is a representation of a (individual) quantity). The definition says:

- 1.19 quantity value = number and reference together expressing magnitude of a (individual) quantity [1, p.12, the parenthesis added].
- 1.7 quantity dimension = expression of the dependence of a quantity on the base quantities of a system of quantities.

Continuous quantities possess a particular structure that can be explicitly characterized as a set of axioms that define such features as identities and relations between magnitudes (sequences of patterns). In science, **quantitative structure** is the subject of empirical investigation and cannot be assumed to exist a priori for any given property.

Every quantity structure has the following fundamental characteristics:

1. Relationships of equality or inequality can in principle be stated in comparisons between particular magnitudes, unlike quality, which is marked by likeness, similarity and difference, differentiation.
2. Additivity may involve concatenation, such as adding two lengths A and B to obtain a third A + B. Additivity is not, however, restricted to extensive quantities but may also entail relations between magnitudes that can be established through experiments that permit tests of hypothesized observable manifestations of the additive relations of magnitudes.
3. Continuity, as a type of quantitative attribute, where continuity means is that if any arbitrary length (dimension), a, is selected as a unit, then for every positive real number, r, there is a length b such that b = ra.

3.9.1 Qualifiers

Quantifiers are words and phrases used to indicate quantity. These include, but are not limited to:

1. A number
2. Few
3. Many
4. Each / every
5. Several
6. An amount
7. Little
8. Less
9. More
10. Much
11. All
12. Some

3.10 Quantity commonly defined

Take note that synonyms for quantity include:

1. Sequence
2. Magnitude
3. Amount
4. Size
5. Degree
6. Weight (not the tool, 'scale')

A quantity is some measured or measurable amount (i.e., quantity or sensation) of some "thing" (of a pre-existing pattern). Therein, a 'unit' of measurement is assigned to selectively identify and categorize (tag, name) the concept[ual thing or dimension] being measured. A quantity is a quantifiable numerical assignment of some property, which is conceptualized as a particular phenomenon (natural process), body (object), or substance (material).

> **CLARIFICATION:** *Magnitude (size) means the numerical value which tells the amount of that physical quantity.*

In measurement, the terms quantity, quantity value, and value, can mean the same thing:

1. A 'quantity' is an amount of something that must have a value.
2. A 'quantity value' is a number and reference together expressing the referential magnitude of a quantity.
3. A 'value' is a number with a reference.

Terminological clarification:

1. **Quantity kind or type (quantity dimension)** – any observable property of any object that can be measured and quantified numerically. A quantity is any property which has size (magnitude) that can be evaluated (compared and integrated into an information model) through some measurement process.
   - For example: length, mass, time, force, energy, electric charge.
2. **Quantity** – observable property of a particular object that can be measured and quantified numerically.
   - For example: length, mass, speed, temperature of a particular object.
3. **Quantity value** – Magnitude of a quantity expressed as a product of a number and a unit.
   - For example: a velocity of m/s.
   - The term 'indication' (result) is used to express the quantity value provided by a measuring instrument.

> **INSIGHT:** *A quantity is anything that can be measured.*

In practice, the terms 'dimension' and 'quantity' tend to become synonymous. Each base quantity is regarded as having its own dimension, and the dimension of a derived quantity is contains the same information about its relation to the base quantities as that provided by the SI unit of the derived quantity as a product of powers of the SI base units. A quantity is also sometimes called a 'quantified dimension'.

Table 10. Measurement > Quantity Comparison*: Table shows two examples (length and power) of the physical dimensions of quantity, physical dimension, and unit.*

Quantity	Dimension	Unit

Length	L	Metre
Power	ML^2T^{-3}	Js^{-1} or watt

Relations between different quantity types/ dimensions are defined by units. A unit is a particular physical quantity, defined and adopted by convention, with which other particular quantities of the same kind are compared to express their value. All physical quantities can be expressed in terms of seven base units.

3.11 A system of quantities

All quantities together with their defined relations form a 'quantity set', otherwise known as a 'system of quantities'. A system of [physical] quantities is a set of quantities together with a set of non-contradictory equations relating those quantities:

1. Quantity objects (quantities) - Base/fundamental and derived quantities.
2. Relational objects (equations) - a set of non-contradictory equations relating those quantities.

In order to establish a system of units, such as the International System of Units (SI), it is necessary first to establish a system of quantities, including a set of equations defining the relations between those quantities.

That which indicates the thing being measured is the reference part, and that which indicates the numerical result of the measurement is the number part:

1. The number part is called a numerical value. Take note here that the number part is also sometimes referred to by just the word "value".
2. The reference part is an entity called a measurement unit, which is defined (VIM, Section 1.9) as a "real scalar quantity, defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the two quantities as a number".

NOTE: *Quantity values are viewed as data by a supra-system.*

3.12 Expressing quantity (in natural language)

A quantity is the combination of a [sequenced] number and a [referential] unit, where the unit may be "pure" (base/fundamental), or a ratio of two relatable units (that describe some function present in the real physical world).

Quantity is expressed by three principal elements (of naming):

1. Identifiers (definite and indefinite) – identify a class of object ("thing") or an example of a class.
   A. **Indefinite identifiers** – indefinite articles (a or an) and the zero article.
   B. **Definite identifiers** – definite article (the), some pronouns (the demonstratives, possessives, anaphoric pronouns), and ordinal numbers. Note, the definite article "the" identifies the particular class.
2. **Quantifiers (definite and indefinite)** – express (or otherwise specifically identify) a quantity.
   A. **Indefinite quantifiers** – express uncertain quantities, such as: a few or a little; many or much; a great number or a great amount of; several; all; plenty of; a lot of; enough; some; any; every; no. The most common logical quantifiers are:
   B. "All" refers to the whole number, to all the elements or units.
   C. "Some" refers to a portion of the whole number, elements, or units.
   D. "Every" refers to all taken separately.
   E. "Each" refers to one example of a class of all.
   F. "Any" refers to all classes.
   G. "None" refers to no one of all.
   H. Definite quantifiers – are cardinal numbers.
3. Nouns of the following three types:
   A. Count unit nouns or countables.
   B. Mass nouns, uncountables, referring to the indefinite, unidentified amounts;
   C. Nouns of multitude (collective nouns).

The word 'number' is a noun of multitude, and stands for either:

1. A single entity, or
2. the individuals making the whole.

3.13 Classifying property-quantities: system quantity dependency

NOTE: *The type of quantity to be measured also impacts measurement requirements.*

Some quantifiable properties (i.e., quantities) are dependent on the quantity, size and extent of the system of which they are a part; and, others are not dependent on the system's quantity.

A quantity, as a sub-part of a system, can depend, or not depend, on the size of the system itself or the quantity (amount) of matter (mass) present in it. A quantity that does not depend on (i.e., is independent) the size of the system expresses an in-tensive type of property/quantity, and a quantity that does depend on the size or extent of the system expresses an ex-tensive property.

NOTE: *The term, tensive, means causing or expressing tension.*

In physics, a fundamental distinction is made in measurement between intensive and extensive quantities (here, a quantity is a property):

1. **Intensive property** - The magnitude of an intensive quantity is independent of the mass of its system (e.g., temperature, density, or pressure). Here, the word quantity may be replaced with property. As in, an intensive property is a physical property of a system that does not depend on the system size or the amount of material in the system. They are independent of the quantity of the system; it is independent of mass. They are independent of the size or extent of the system.
2. **Extensive property** - The magnitude of an extensive quantity is additive (like mass, volume, or energy). Here, the word quantity may be replaced with property. An extensive property is additive for subsystems. This means the system could be divided into any number of subsystems, and the extensive property measured for each subsystem; the value of the property for the system would be the sum of the property for each subsystem. They depend on the quantity of the system; it is dependent on mass (as a variable). They depend on the size and extent of the system.
   A. Extensive quantity
   B. Potential energy (non-conserved quantity):
   C. Unavailable energy;
   D. Available energy (heat interaction as entropy, and work interaction)
   E. Mass (conserved quantity)

Note that in some disciplines, there is no recognized type distinction between intensive and extensive quantities.

3.13.1 Quantity and quantity value in mathematics

NOTE: *Mathematically, a quantity is a scalar. However, a vector or a tensor, the components of which are quantities, is also considered to be a quantity.*

From a mathematical perspective, a 'quantity value' is an algebraic term. In algebra, the concept 'term' represents a mathematical expression composed of two different parts: the number part (a.k.a., numerical coefficient) and the variable part (often notated as "x" or "y"). Similarly, the result of a measurement is, mathematically speaking, a 'term', for there is a number part and a unit (variable) part, which may be expressed [in notation] with constants and other variables, and equality symbols may be included to form equations from which [statistical] mathematical operations may be performed [to acquire more/new information].

The language of algebra has no meaning in and of itself. The theoretical mathematician deals entirely within the realm of the formal language and is concerned with the structure and relationships within the language. The applied mathematician or statistician, on the other hand, is concerned not only with the language, but the relationship of the symbols in the language to real world objects and events. The concern about the meaning of mathematical symbols (numbers) is a concern about measurement.

Magnitude (how much?) and multitude (how many?) are the two principal types of quantities, which may be further divided as mathematical and physical. The essential part of mathematical quantities consists of having a collection of variables, each assuming a set of values. These can be a set of a single quantity, referred to as a scalar when represented by real numbers, or have multiple quantities as do vectors and tensors, two kinds of geometric objects.

Quantities can be used as arguments of a function, variables in an expression (independent or dependent), or probabilistic as in random and stochastic quantities.

Number theory covers the topics of the discrete quantities as numbers: number systems with their kinds and relations. Geometry studies the issues of spatial magnitudes: straight lines, curved lines, surfaces and solids, all with their respective measurements and relationships.

Algebra operations are used for performing computations with quantities. Here, algebra operations allow for computations with uncertain values. These operations enable model-level simulations that consider data uncertainty and units (encoded through referential databases). In application, [physical] information processing requires a computational kernel for computing quantities.

NOTE: *Quantities may be integrated with modeling language, as in the case of UML.*

3.14 Physical and non-physical quantities

INSIGHT: *All physical measurements are geometric measurements.*

There are two categories of quantities as viewed from the physical, material perspective:

1. A **physical quantity** is a quantity that can be used in the mathematical equations of science and technology. Systems exist along a spatial-temporal continuum. Physical quantities are used in science and engineering because they are objective, and hence, may be used for logical inquiry and construction.
   A. The material properties of the surrounding world include: The existence, operation,

placement, and composition of material (spatial-temporal) objects.
B. Sud-divided into base and derived quantities.
2. A **non-physical quantity** is a quantity that cannot be measured by any mean or media. These quantities do not have magnitude of themselves. A non-physical quantity is a qualitative measure (and, non-physical quantities can have order). Some common example of non-physical quantities are: feelings, angriness, rudeness, etc. For these measurements (as in, the measurement of non-physical quantities), it is not possible to ensure traceability because of their exclusive nature as substantiated solely by the author. It is relevant to note here that it is scientifically understood (in neurophysiological flow literature) that biology responds before psychology (or with psychology, in the case of highly intelligent consciousness). And, all aspects of biology and electromagnetism area measured as physical quantities (and not, non-physical quantities). Biology can be quantifiably measured.
   A. The immaterial properties of the inner world include: anything experiential which can be described as feeling or e-motion. Non-physical quantities exist only in the mind of people either as reflections of properties of the real world, or in the form of people's own understandings (...to which the body responds faster than the mind, and can be accurately, traceably quantified).
   B. Immaterial properties do not only exist in people's minds without any material dimension, in fact, the human body express in more or less optimal, or disturbed, functioning.
   C. Sud-classified (sub-divided) into simple (a.k.a., base) and compound (a.k.a., derived) quantities. The simple physical quantities are constituent parts of the compound quantities, the latter being composed of a set of simple or compound quantities of a lower level.

INSIGHT: *The human organism cognates the material world by means of sense organs, through organoleptic measurements of its quantitative characteristics, while the immaterial world is perceived through measurements of its qualitative characteristics.*

When measuring physical quantities, standard reference objects and/or machines may be used, such as: length gauges (rulers) to measure length, and mass gauges (weights) to measure mass.

It is not accurate to say that non-physical quantities (qualities) only measure human opinion; they can also measure felt (experiential) fulfillment. Organisms express bio-electrical responses to particular environments. Therein, there is an ordering between suffering and well-being.

There are cases where the non-physical (immaterial) quantity being measured is a human opinion. Human opinion is subjective estimation. And, human opinion is largely dependent on an individual's specific life circumstances (social, decision, lifestyle, and material, without reference to an exist world). Opinion is largely dependent on exposure to information, personal preference, social influence, personal well-being, environmental factors, tastes, health, etc.

Here, the measurement of an immaterial property (opinion) comes down to a comparison of manifestations of this property, and, as a result, the question about when the property has manifested itself in a greater degree can be answered.

From the acquisition of opinions expressed about the manifestation of an immaterial property comes a comparative, quantitative estimate (i.e., a single measurement is taken on an ordinal scale). Here, one opinion is one measurement unit (along an ordinal [quantity] scale). And, the number of opinions is a quantitative characteristic of a non-physical quantity (a quality).

Note that besides felt human fulfillment and ecological well-being, human opinion has no fixed dimension, and hence, without the concepts of fulfillment and well-being, it is separated from a unified model of understanding and constructing.

3.15 Classifying physical quantities

Physical quantities can be classified in a number of ways:

- **Electrical quantities:** resistance, capacitance, permeability, permittivity (voltage, current, inductance, electrical power, electrical energy).
- **Non-electrical quantities:** fluid pressure, displacement, torque, temperature, area, volume.

The concept of a physical quantity can be classified according to whether it is electrical or non-electrical:

- **Length-type quantities:** The quantities diameter, circumference, and wavelength are generally considered to be quantities of the same kind, namely of the kind of quantity called length.
- **Energy-type quantities:** The quantities heat, kinetic energy, and potential energy are generally considered to be quantities of the same kind, namely of the kind of quantity called energy.

Note: *Many traditional economists hold the view that utility is measured quantitatively, like length, height, weight, temperature, etc. This concept is known as cardinal utility concept. On the other hand, ordinal utility concept expresses the utility of a commodity in terms of 'less than' or 'more than'.*

3.15.1 The dimensional property attribute of [classified] physical quantities.

A quantity as an information data point may be either a scalar quantity or a vector quantity. In physics, there are two principle types of physical quantities [that can be measured]: scalar quantities and vector quantities. These two categories are typified by what information they require. Scalars require one piece of information (a number), and vectors require two pieces of information (a number and [coordinated] direction). A scalar measurement is the measure[d result] of a scalar quantity, and a vector measurement is the measure[d result] of a vector quantity.

3.15.2 Scalar – magnitude only (a scalar represents the magnitude or size of a quantity)

A scalar variable is a variable that holds an individual value (single number). A scalar number is a number used to measure some quantity to any desired degree of accuracy.

1. **Scalar quantities** - Scalars are used to describe one dimensional quantities, that is, quantities which require only one number to completely describe them. A scalar quantity represents a physical quantity specified by magnitude. Scalar [quantities] are physical [quantities] represented by a single number [magnitude] and no direction. Scalars can be represented by a |x| matrix. In visualization, scalars are numbers.
   A. Examples include, but are not limited to: temperature, time, height, speed, mass, volume, location along a line (1D). Position and distance are scalars, because there is no direction.
   B. one scalar • another scalar = a scalar
   C. one scalar • a vector = a vector
2. **Scalar measurement** – a numerical descriptive signifier of a quantity, magnitude, or size of a bounded sensation. A scalar measurement can be represented with a number alone (with relevant units). It describes a quantity, magnitude or size of a measurement alone. For example, mass and temperature are scalar measurements.

3.15.3 Vector – magnitude and direction (a vector represents the magnitude, size and direction of a quantity)

A vector variable is a variable that holds more than one individual value.

1. **Vector quantities** - Vectors are used to describe multi-dimensional quantities. Multi-dimensional quantities are those which require more than one number to completely describe them. Vectors, unlike scalars, have two characteristics, magnitude and [a systematically coordinated] direction. The magnitude of a vector is its "length" (or other quantity in some units). Vector quantities are [not necessarily physical quantities and] are represented by a number (magnitude) and a direction. The direction is usually given in terms of some angle. Vectors can be represented by a lxA ([4 2], row vector) or an nxl ([4 / 2], column vector) matrix. Vectors are one dimensional. In visualization, vectors are arrows.
   - Examples include, but are not limited to: location in a plane (2D), location in space (3D), velocity, acceleration, force, displacement, momentum.
   - one vector • another vector = a vector
2. **Vector measurements** – a numerically descriptive signifier of the relationship between the two fundamental dimensions of magnitude (size or quantity; inertia and acceleration) and direction (force and motion). Vectors are a form of measurement that conveys both magnitude (size or quantity) and direction (with relevant units). Velocity is a good example of a vector measurement (the object moves at 3m/s to the East). It is not to be confused with speed, which is scalar (e.g., the object moves at 3m/s). When visualizing vector measurements, an arrow is a common symbol for the vector.

Vectors (vector numbers) can be added together in ways that scalars (scalar numbers) cannot.

> **NOTE:** *A vector space is defined as a set of vectors, a set of scalars, and a scalar multiplication operation that takes a scalar k and a vector v to another vector kv.*

The term "scalar" comes from linear algebra, where it is used to differentiate a single number from a vector or matrix.

3.15.4 Standard scalar measurement

In standard scalar measurement, points exist along a principal standard measurement scale, the scale of cardinal numbers. The following are ways of taking a standard scalar measurement; if, for example, "you" measure the width of "your" desk, "you" take a tape measure and align it with a point on the desk, and then, "you" count off the number of centimeters or inches. Or, if "you" measure the outdoor temperature at the present moment, "you" take a thermometer outdoors and count off the number of degrees Celsius or degrees Kelvin. If "you" are sitting in a room measure the number of humans in the room, "you" count them. This type of measurement is known as standard scalar measurement, since each individual instance of it results in a numerical value that refers to a point on some particular standard measurement [conceptual unit] scale, such as: inches, centimeters, degrees Kelvin, degrees Celsius, pints, liters, bushels, grams, ounces, light years, volts, ohms, etc. A standard scalar measurement is a point on a standard measurement scale.

1. **Absolute scale** - When measurement involves simply counting out the number of a set of items or events according to the series of cardinal numbers (i.e., one, two, three, four, etc.), then the scale of measurement is otherwise known as an absolute scale. An absolute scale is a system of measurement that begins at a minimum, or zero point, and progresses in only one direction. An absolute scale begins at a natural minimum, leaving only one direction in which to progress. When counting with cardinal numbers (0,1,2,3,4,5,...), the cardinal number set represents the scale. An absolute scale can only be applied to measurements in which a true minimum is known to exist.
    A. Absolute scales are typically used in science and anywhere precise values are needed in comparison to a natural, unchanging zero point.
    B. Measurements of length, area and volume are inherently absolute, although measurements of distance are often based on an arbitrary starting point.
2. **Relative (or arbitrary) scale** - All other commonly recognized measurement scales are relative, in the sense that they are designed to measure, not the absolute number of items or events, but rather the 'magnitude' of some particular attribute (e.g., length, width, weight, temperature, velocity, electrical potential, etc.) relative to the units [of some particular scale that has been designed, or has evolved, for taking the measure of that attribute].

In concern to several important measurable physical quantities:

1. Weight can be absolute, such as atomic weight, but more often they are measurements of the relationship between two masses, while measurements of speed are relative to an arbitrary reference frame.
2. Temperature has a known minimum, absolute zero (where all vibrational motion of atoms ceases), and therefore, can be measured either in absolute terms (kelvins or degrees Rankine), or relative to a reference temperature such as the freezing point of water at a specified pressure (Celsius and Reaumur) or the lowest temperature attainable in 1724 (Fahrenheit).
3. Pressure is a force that can be measured absolutely, because the natural minimum of pressure is total vacuum. Pressure is frequently measured with reference to atmospheric pressure rather than on any absolute scale, relative to complete and perfect vacuum. And, with measurements of things like blood pressure or tire pressure, a measurement relative to air pressure is a better indication of "burst pressure" (damage threshold) than an absolute scale.

3.16 Conceptual composition of 'quantity' by attribute

The concept of a [measurable] 'quantity' is sub-composed of the following attributes (every quantity may be categorized according to these four sub-conceptions):

1. **Measure[able quantity]** (it has a physical referent) – The physical variable. For example, molecular density. If something has a quantity, then it is measurable.
2. **Dimension** (it has a dimension or is dimensionless) - A dimension is a measure of a physical variable (without numerical value[s]). It could be said that a dimension refers to the extent of all possible units of a given type. For example, length is a dimension. The terms measurable quantity and dimension are often synonymous.
3. **Unit** (it has a unit name-quantity) - a unit is a logical process ("way") to assign a number (or, "measurement") to that dimension. A unit is a name (and description) of the value being measured for. For example, the meter is a unit of length.
4. **Value** (it has a numerical value) – the number, logically sequenced to represent the 'magnitude' or 'amount' of an instance of the physical variable (a pattern). For example, when there are three interval patterns of the category meter, then the value is 3.

NOTE: *There are 7 quantities on which all international[ly standardized, ISO] quantities are based. Yet, a system of three base units, consisting of units of mass, length, and time, is sufficient to express the units of all other mechanical quantities.*

3.17 Measureable quantities

NOTE: *The concept 'measure' conveys the idea that measurement involves a chain of coherently connected relationships, which start the sequencing of their relationships at a source, and with which ("against") all new information of* *a like kind is compared (for patterns). The source of the chain of conceptual relationships is called its: base, fundamental, or axiomatic conception.*

There are two (or at least one, which becomes two) axiomatic/base conceptions of a quantity in science and measurement:

1. **Base/fundamental quantities** are those quantities that are common to any object or event. For example: length, mass, charge, time. A base quantity is a conventionally chosen quantity. No base quantity can be expressed as a product of powers of the other base quantities. Hence, it is said that base quantities are mutually independent (axiomatic).
    - **System of base quantities** – No member of the subset can be expressed in terms of the others. In terms of expression, every other quantity can be conveniently expressed in terms of base quantities. Normally, the symbol of a quantity is written in italics, and that of its dimension in capital letters.
2. **Derived quantities** are quantities formed by combining two or more base quantities (using multiplication or division, algebra). For example, area (length x width), volume (length x width x height, a3), speed (distance/time). A quantity in a system of quantities, which is defined in terms of its base quantities.

Or, the conception of physical quantity could be viewed as follows:

1. Base axiom quantities.
2. Derived mathematical operational quantities.

A complete system of quantities includes both base and derived quantities.

3.17.1 The dimensional attribute of quantity

Dimension refers to the name of the quantity being measured. The "dimensions" of a quantity refer to the basic/fundamental composition ("nature") of the quantity (i.e. how the quantity is related to the base/fundamental quantities of existence: length, mass, time, charge, etc). Every measurement consists of an empirical comparison of dimensions.

In concern to dimensionality, the measurement of a physical quantity may be classified as one of the following:

1. **Dimensionless with units** – has units, but no dimensions.
    - Quantities having units, but no dimensions include, but are not limited to: plane angle, angular displacement, solid angle. These physical quantities possess units, but they do not possess dimensional formulas.
2. **Dimensionless without units** – has no units, and no dimensions.
    - Physical quantities having no units, cannot possess dimensions: trigonometric ratios, logarithmic functions, exponential functions, coefficient of friction, strain, Poisson's ratio, specific gravity, refractive index, relative permittivity, relative permeability. All these quantities neither possess units nor dimensional formulas.
3. **Dimensioned with units** – has units and dimensions.
    - Quantities having both units and dimensions include, but are not limited to: area, volume, density, speed, velocity, acceleration, force, energy, etc.

A dimensionless quantity is a quantity to which no physical dimension is applicable. It is also known as a "bare" number, "pure" number, or a quantity of dimension one. A "pure" number is a number with no unit attached. For example, 2 is a dimensionless quantity, 2 apples, is not (as in, the dimension is "fruit'). Other dimensionless quantities include, for example: 1, i, π, e, and φ, 1/φ, and 1/φ-3 or φ3.

All "pure" numbers are dimensionless and unitless quantities, for example 1, i, π, e, and φ. A "pure" number is a kind of a number that has a dimensionless quantity, and does not have a physical unit. Note here that the use of the word "pure" as a qualification of number, is not useful, because the numeric portion of a dimensioned number is also "pure" in the sense that it is a value.

Presently, given what is known, there are between five and seven primary dimensions (or dimensional [physical] quantities) to material reality. Primary (a.k.a., basic or fundamental) dimensions are defined as independent or fundamental dimensions, from which other dimensions can be obtained. In other words, these dimension are axiomatic to our conception of the dimension of something real.

Hence, remember that when working in mass the base standard to which every other standard and mass measurement is being compared, is the *kilo*+gram (kilogram), and not the *null*+gram (gram). The base unit is a [prefix] multiple of the one unit, kilo-.

3.17.2 Unit attribute

Whereas a quantity is a measurable property for a phenomenon, body or substance, a measurement unit is chosen by convention as the reference to which measurements of that property refer.

The presence of the 'unit' signifies the type of relationship that exists between the number part of a measure (the 'value') and the dimension part of a measure. "Units" refer to specific ways of reporting (or denoting) a quantity.

A unit is the label of a scalar quantity, defined and adopted by cooperation/convention, with which any other quantity of the same dimensional kind can be compared to express the ratio for the two quantities as a number.

> **NOTE:** *The ratio of two quantities of the same dimensional kind is a pure[ly dimensionless] number.*

The measurement unit allows for the [numerical] value [of the quantity] indicated for an object or event, to be compared with the value indicated for the measurements' reference dimension (e.g., mass, length, etc.). The reference dimension is the reference used to calibrate the measurement system (i.e., the relative source of all standard comparisons).

The measuring unit is the relational signifier assigned to the numerical measure, to identify it out of all potential possible [unitized] representations.

Corresponding to a system of quantities, where there are base and derived quantities, there is also a system of corresponding units, where there are base and derived units. A system of [measurement] units is a set of measurement units corresponding to every quantity in the system of quantities. The set of system units consists of:

1. **Base units** (a.k.a. system of base units)
2. **Derived units** (a.k.a., system of derived units)
3. **Dimensionless quantities** (or, quantities of dimension 1)

For every base 'quantity' (as a concept), there exists a base 'unit'. Base units can be used to build and/or express newly "derived" units (Read: derived units). The principal set of units (also sometimes viewed as a subset of units) from which all other units are expressed, is called a [system of] base units.

> **NOTE:** *The magnitude of any given quantity can be expressed by (i.e., associated with) a number equal to the ratio of the quantity to its unit.*

The following are important principled clarification on the conception of base units:

1. There is only 1 base [standardized] unit for a quantity. In every system of units there is only one base unit for each base quantity. For example, in the SI, the metre is the base unit of [the dimensional quantity] 'length'. The centimeter and the kilometer are also units of length, but they are not base units in the SI.
    - **A [unit] conversion factor** – is a ratio of two measurement units of quantities of the same kind. For example, km/m=1,000 and thus, 1km=1,000m; here, 1/1000 is the conversion factor (ratio).
    - In the SI, there are seven base [quantity] dimensions. Mass is the only base/fundamental dimensional quantity whose base [standardized] unit is a conversion factor, the kilogram (Read: kilo as a 1000 conversion factor combined (+) with 'gram' as unit mass). The other base dimensions are standardized to a non-conversion factor base. In other words, notice how length is meter, time is second, amount of substance is mole, but mass is kilogram. Mass is not standardized to a zero-conversion factor.
2. A base unit may serve for a derived quantity of the same dimension. For example, when rainfall is defined as volume per unit area, and the meter is used as a coherent derived unit (in the SI).
3. For any number of entities, the number one, symbol "1", can be regarded as a base unit in any system of units.

> **NOTE:** *A system of three base units (mass, length, and time) is sufficient to express the units of all other mechanical quantities. However, a system of four base quantities is required to express each and every other quantity.*

A particular quantity "can" be reported in many different kinds of units, but it will always have the same dimensions. It is best to have a unified measurement model where a particular quantity can only be reported with one particular kind of unit (that may be orderly scaled itself), forming a 1 to 1 matching (pairing) between units and dimensions. For example, in early 21st century society, force (which can be expressed F=ma) has dimensions of mass x length/time2. Here, force can be expressed in different units, which leads to confusion and is a sign of a lack of social cooperation and conceptual integration: Newtons, ergs, pounds-cm per square hour, pressure, force, and torque.

3.17.3 Quantities of the same kind

Quantities of the same kind will have the same unit, but two quantity values having the same unit do not have to be of the same kind. For example, the unit of 'mass density' and of 'mass concentration' is kgm-3, but these are not quantities of the same kind. Similarly, the measurement unit of both frequency and activity of radio nuclides is s-1, but they are not quantities of the same kind. The unit in each [conceptually modeled] case is given a unique unit label, namely frequency is hertz (Hz) and the activity of radio nuclides is Becquerel (Bq).

3.17.4 Unit prefixes (unit multiple prefixes)

Because the continuum of each physical unit is so large, notation via multiple(s) becomes necessary for human cognition. A multiple of a unit is indicated by a prefix. The prefixes designating the multiples and submultiples of physical units (e.g., length, frequency, power) are: deca-, hector-, kilo-, mega-, ...

3.17.5 Value attribute (number)

Here, the 'value' is the quantity's numerical association, and the 'quantity value' is the value (number) and unit (reference) together. The quantity's value is the measure's number, and the reference is the measurement unit. To be more specific, a 'quantity value' may be expressed as either:

1. A number and a measurement unit (the unit one is generally not indicated for a quantity of dimension one).
2. A number and a reference to a measurement procedure.
3. A number and a reference material.

A 'quantity' value maintains the following characteristics:

1. The number can be real or complex.
2. A quantity value can be represented in more than one way.

The size (magnitude) of a quantity is expressed as a number accompanied by a measurement unit, and if appropriate, by additional reference to a measurement procedure or a reference material. Here, the term 'quantity value' refers to a number "multiplied by" its tagged unit (or reference), forming a mathematical 'term' upon which calculation operations are possible.

Clarification: The term "true" value is sometimes used in common parlance. The concept of a 'true value' has been redefined in metrology. It used to mean: The true value (of a quantity) is the value which characterizes a quantity "perfectly" defined, in the conditions which exist when that quantity is considered. The concept of a 'true quantity value' now means: a quantity value consistent with the definition of a quantity.

3.18 Conceptual systems model of measurement

Measurement may be represented as a logical [conceptual] information system with inputs, operational processes, and outputs.

1. Inputs [static]: logic, definitions, algorithms, reference standards, units. Answers the question, What is required for measurement?
2. Inputs [dynamic]: quality (property, attribute, characteristic), quantity, measurand. Answers the question, What is being measured?
3. Processes: calibration, measurement. Answers the question, How does measurement occur?
4. Outputs: quantity value (a.k.a., quantity or value), indication, result, term. Answers the question, What is the output of measurement?

3.19 Input (static): Measurement standards

Any measurement requires a measurement standard (Etalon), which is the embodiment of the definition of a given quantity, with state quantity value and associated measurement uncertainty, used as reference.

There is a hierarchical mapping to the concept of a standard [of comparative] reference. The primary (base) standard (in the hierarchy) is checked (i.e., calibrated) to be the same value as new standard at one level lower in the mapping chain. This new, second (and not primary) standard can be used for direct comparison, or a new lower level (third) standard could be checked (i.e., calibrated), and the process continues. All standards are pre-aligned or pre-calibrated, except for the primary, which acts as the standard for all calibrations.

Working/operational level standards are lower in the hierarchy, and that which is closest to a pure conception of the object/event being measured is higher in the hierarchy. Herein, working-level standards are, in turn, calibrated against higher-level standards, which reference (trace, map, or have been demonstrated to align) back to a primary [procedural unit] system.

> **NOTE:** *A proper chain of traceability must include a statement of uncertainty at every step.*

The [principal and principle] standard is the physical representation of the units defined in the system of units.

In measurement, standards define the units and scales in use, which allow for comparison of measurements made in different times and places.

Simplistically, a standard is a process or system that has been agreed upon (formally or informally). Standards emerge when cooperation is present, or when safety is required. Therein exists the necessity for a repeatable process for comparing within a single category some known quantity and/or value with some to be known quantity and/or value.

Standards define that which is required to effectively and cooperatively perform some function (or, "do some thing"). Take note, however, that there are multiple kinds of standards, and their meanings may vary slightly: measurement standards; standards of practice; protocol standards; etc. In general, however, the term means a well-defined and agreed upon set of processes.

Here, measurement standards are "devices" (tools, processes, and objects) that represent the standard system's unit (e.g., SI) in a measurement.

A [measurement] standard is a fundamental reference for determining the value of new information moving into a measurement system. The four common definitions of a measurement standard are:

1. Measurement standards are those devices,

artifacts, procedures, instruments, systems, protocols, or processes that are used to define (or to realize) measurement units, and on which all lower echelon (less accurate) measurements depend.
2. A measurement standard may also be said to store, embody, or otherwise provide a physical quantity that serves as the basis for the measurement of a new quantity of some thing [that the measurement standard accounts for].
3. A standard is the physical embodiment of a measurement unit, by which its assigned value is defined, and to which it can be compared for calibration purposes.
4. A standard is a unit of known quantity or dimension to which other measurement units can be compared.

Multiple measurements of a similar category or thing require a 'standard' to which the measuring instrument and/or observer will refer when determining the measure.

> **NOTE:** *Any quantity used as a standard of reference is a unit of measure.*

There are two primary measurement standard categories:

1. **The base/fundamental physical [standard of] reference** – a fundamental physical constant is used as the reference. The real physical world is the metric.
2. **The derived [standard of] reference** – something has been designated by a conscious observer or decisioning system to act as a reference standard. Some object (or digital process) is used as the reference standard. The fundamental physical referent is the reference.

When the word 'magnitude' is used, then there are two measurement system magnitudes:

1. **Fundamental magnitudes (fundamental measurement procedures)** – magnitudes determined from measurement procedures that satisfy the conditions of additivity and do not involve the measurement of any other magnitude. Here, ordering and concatenation operations are active.
2. **Derived magnitudes (derived measurement procedures)** – magnitudes that can only be determined through their relations to other, fundamentally measurable magnitudes. Note here that additivity is not necessary for a measurement.

When the word 'quantity' is used, then there are two measurement system quantities:

1. **Fundamental quantity (a.k.a., base quantity, basic quantity, or metric quantity)** – defined by specifying a[n operational] measurement process.
    - Fundamental base[-ic] system of dimensional units [of measure-ment]
2. **Derived quantity** - Defined by algebraic[ally expressed] combination of base units.
    - Derived/defined units of relational dimensions [of measure-ment]

3.20 *Input (dynamic): The measurand (the measured variable)*

The measurand is a[n object] name and a description of a (particular) quantity intended to be measured) as the first step in the process of measurement. This step or phase is known as the "problem of definition". The measurand is a description of the specific quantity intended to be measured. The specification of the measurand should be sufficiently detailed to avoid any ambiguity. The measurand is not just another name for analyte. Analyte is the component represented in the name of a measurable quantity, whereas measurand refers to a specific quantity to which quantity values are expected to be attributed by means of a measurement.

The measurand is also sometimes called the 'state name variable'. Technically, that which is being measured is the state of a system, which have been given a [logical] name, and represents a variable (static or dynamic) in the operation of the system. Wherein, more information is being gathered about the system by inquiring into a bounded sub-set of the system.

Hence, a measurand is a particular quantity subject to measurement. Measurand is the [label given in the context of measurement to the] quantity intended to be measured. The measurand is the measured variable.

The problem of clearly defining the measurand ("that which is measured") is called the problem of definition, and it has two parts, one simple and one rather subtle and complex.

The first and simplest part of the phase of definition, relates to the identification (pattern recognition, categorization) of the quantity measured. In principle, all that is required is to provide sufficient information to allow the measurement to be repeated, or otherwise predicted similarly. Herein, influences may also have to be specified.

The second and most difficult part of the problem of definition relates to the technical definition of the attribute that is being measured. In the case of 'temperature', what is the meaning of 'temperature'? The temperature of a system is strictly defined only in conditions of thermal equilibrium, that is no net flow of heat between any of the components of the system.

Measurements with definition problems (i.e., incoherencies) are often the source of great argument.

The telltale sign of a definition problem is a measurement where the result seems to vary with the measurement technique.

The standard definition of the term 'measurand' was once different. In fact, the former definition of measurand was, "The quantity subject to measurement." It could be said that a quantity is experimentally 'subject' to the interaction with a measuring instrument (in part, because the measurement instrument is designed and applied with an intent).

3.21 Measurement processes

In addressing measurement problems, it is necessary to have a conceptual model of the measurement process.

3.21.1 Calibration

Calibration is comparison of a measurement device against a standard and adjustment if necessary. Calibration is the process of checked some quantity against a known standard, and adjusting the quantity [to match the known standard] if necessary. Calibration is a comparison of an item to a standard that is closer to the primary (or the primary) standard (e.g., SI), also known as a higher-level standard. Adjustment of the lower-level standardized device is part of the operation required (as in, if the lower-level device does not align correct). Such comparison requires traceability of the calibration. Traceability is defined as an unbroken chain of comparisons to National or international standards (e.g. standards maintained by NIST), AND stated uncertainties at each step. The traceability of course needs to ultimately go to SI.

Calibration is a set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure, or a reference material, and the corresponding values realized by the standard.

Calibration can be further defined:

1. **Calibration** - operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication.
2. **Calibration** is the procedure of establishing a relation (adjusting or checking) a scale so that the readings of the (lower-level standard) instrument conforms to an accepted standard (higher-level standard).
3. **Calibration hierarchy** - sequence of calibrations from a reference to the final measuring system, where the outcome of each calibration depends on the outcome of the previous calibration.

The results of a calibration include:

1. The result of a calibration permits either the assignment of values or measurands to the indications or the determination of corrections with respect to indications.
2. A calibration may also determine other metrological properties such as the effect of influence quantities.
3. The result of a calibration may be recorded in a document sometimes called a calibration certificate or a calibration report. (International Vocabulary of Basic and General Terms in Metrology)

In a calibration experiment, the analyst typically prepares a set of calibration solutions (also known as, calibrators, standard solutions, or working standards; i.e., a set of measurement standards). When measured, each of them gives rise to an indication (signal, response). The relation $y = f(x)$ between the indication and the corresponding quantity value is called a calibration curve. The uncertainty of the calibration will include contributions from the uncertainty of the measurement standards, variation in indications, and limitations in the mathematical model when establishing the relation $y = f(x)$.

Calibration and verification are carried out on measurement equipment to determine (and adjust if necessary) their accuracy.

In application, calibration is the process of mechanically or electronically setting the parameters for a measuring instrument.

In concern to calibration, there are two types of measurement instruments (devices, equipment, tools, etc.):

1. **Adjustable** – The instrument's operation may be changed (adjusted) to result in different measurement readings (indications) for the same quantity under the same conditions. Adjustable instruments are calibratable after their creation. Calibration may occur on adjustable measuring instruments after their creation (e.g., micrometers, scales, verniers, etc.). Because the accuracy of adjustable instruments will drift naturally over time, these instruments must be periodically calibrated against a higher-standard.
2. **Non-adjustable** – The Instrument's operation cannot be changed (i.e., it is non-adjustable). Non-adjustable instruments are calibrated once during their creation, which cannot be changed without re-creating the instrument.

Calibration process ("pipeline") involves:

1. Identification
    - Purity of substance
2. Verification
    - Secondary reference materials (RMs) and controls
3. Recognition

A measurement standard is the prerequisite of any calibration, which is the operation that establishes a relation between the quantity value provided by a measurement standard and corresponding device outputs (Read: indications), with associated uncertainties. A calibration may be expressed by a calibration diagram, calibration curve, or calibration table. It can be an additive or multiplicative correction.

> **Note:** *Calibration should not be confounded with the adjustment of a measuring system, sometimes called autocalibration, which is the set of operations (zero, offset, and span or gain adjustment) performed on a measuring system so that it provides prescribed outputs (indications) corresponding to given values of a quantity to be measured. Therefore, in practice, the best performance will be obtained by a first calibration to determine the approximate magnitude of the adjustment needed, then the adjustment, then a final recalibration.*

Calibration is an operation. Under specific conditions, it has a first step that establishes relations between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties. And, in a second step, use this information to establish a relation for obtaining a measurement result from an indication.

A calibration measurement is traceable to NIST when the parameter being measured is clearly defined:

1. **An unbroken chain:** Comparisons from the measurement result reported by a laboratory all the way back to a nationally recognized primary standard (NIST).
2. **Documentation** – Every link in the chain must be performed according to documented procedures, and the results of these procedures must be documented. This documents the measurement system.
3. **Competence** – Laboratories performing steps in the chain must have demonstrated competence as demonstrated by accreditation to ISO 17025.
4. **Measurement assurance** – The laboratory must systematically establish the status of reference materials and working standards at all times pertinent to a given result.
5. **Measurement uncertainty** – The measurement uncertainty must be determined for each link in the traceability chain, and the measurement uncertainty must be reported for the final measured result. Uncertainty reporting is mandated for ISO accredited calibrations.

3.21.2 Measurement equipment calibration

When uncertainty is relevant (in a decision), the uncertainty reported by a measurement device system (or calibration certificate) is necessary to calculate the uncertainty of measurement.

The calibration system metadata (calibration certificate) must contain specific information to fulfill the purpose of supporting traceable measurement:

1. Identity of device
2. Location of device storage
3. Location of device usage
4. Identity of device user
5. Measurement data

The following may affect performance of measurement equipment and create uncertainty with their reliability:

1. Drift
2. Environmental factors
3. Component age
4. Shock
5. Misuse

For Community Habitat Service System operations, the equipment must be properly:

1. Monitored
2. Maintained
3. Used
4. Stored
5. Transported

3.21.3 Conditions for calibration

Calibration requires traceability. Traceability requires:

1. An unbroken chain of comparison to National or international standards; and
2. Stated uncertainties at each step.

> **NOTE:** *The only way to "prove" that measurements are right (i.e., there is a "right measurement"), is to prove that their uncertainty is low enough to allow the desired conclusions to be drawn from the results, such as whether or not a workpiece meets its specification.*

3.22 Measurement output

Two types of measurement outputs

- **Instrument indications (or "readings")** - these are properties of the measuring instrument in its final state after the measurement process is complete.

- **Measurement outcomes (or “results”)** - these are knowledge claims about the values of one or more quantities attributed to the object being measured, and are typically accompanied by a specification of the measurement unit and scale and an estimate of measurement uncertainty.

3.22.1 Uncertainty

Uncertainty is a parameter associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand.

3.22.2 Properties of the output (result) of measurement

Accurate measurement requires the following principle enablers (and accompanying tools):

1. **Traceability** – enables comparison over time and place.
2. **Uncertainty** – enables meaningful comparison of results.
3. **Confidence** – enables meaningful interpretation of results.
    - Results are only useful when the same pattern (“thing”) is compared.
    - Where uncertainty is assessed qualitatively, it is characterized by providing a relative sense of the amount and quality of evidence (that is, information from theory, observations or models indicating whether a statement or proposition is true or valid) and the degree of the understanding.

3.22.3 Traceability

Measurement includes an experimental (primary method) and representational component (additional standards), the latter implying the requirement for metrological traceability.

Metrological traceability is the property of a measurement result, whereby the result can be related to a reference [unit] through a documented unbroken chain of calibrations (comparisons), all having stated uncertainties. Measurability requires [metrological] traceability. Only measurement results are traceable.

There are five sub-conceptions to the definition of [metrological] traceability:

1. An unbroken chain (or relationships)
2. An uncertainty of measurement
3. Documentation
4. Reference to the formal standard (SI units)
5. Calibration intervals

3.22.4 Claiming traceability

The provider of the result of a measurement is responsible for supporting its claim of the traceability of that result or value.

To support a claim, the provider of a measurement result must document the measurement process or system used to establish the claim and provide a description of the chain of calibrations that were used to establish a connection to a particular specified reference. There are several common elements to all valid statements or claims of traceability:

1. A clearly defined particular quantity that has been measured.
2. A complete description of the measurement system or working standard used to perform the measurement.
3. A stated measurement result, which includes a documented uncertainty.
4. A complete specification of the reference at the time the measurement system or working standard was compared to it.
5. An ‘internal measurement assurance’ program for establishing the status of the measurement system or working standard at all times pertinent to the claim of traceability.
6. An ‘internal measurement assurance’ program for establishing the status of the specified reference at the time that the measurement system or working standard was compared to it.

The user of the result of a measurement is responsible for assessing the validity of a claim of traceability.

3.22.5 Measurement as a feedback calculation sub-systems

In the context of decisioning, there are [at least] two feedback calculation sub-systems:

1. Measurement systems are used to assess existing entities by numerically characterizing one or more of its attributes.
2. Prediction systems are used to predict some attribute of a future entity, involving a mathematical model with associated prediction procedures:
3. Deterministic prediction system – the same output will be generated for a given input. The output of deterministic models is fully determined by the parameter values and the initial conditions.
4. Stochastic prediction system – the output for a given input will vary probabilistically. Stochastic models involve some inherent probability (“randomness”), wherein the same set of parameter values and initial conditions will lead to more than

one output.

Measures and predictions may (sometimes, must) be validated. Validation routines determine if:

1. A measure is valid if it accurately characterizes the attribute it claims to measure.
2. A prediction system is valid if it makes accurate predictions.
3. Validation is defined in ISO 9000 section 3.8.5 as "confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled".
4. The process of ensuring that the measure is a proper numerical characterization of the claimed attribute by showing that the representation condition is satisfied.
5. The accuracy of prediction systems are validated through the process of establishing empirical means (i.e., by comparing model performance with known data in the given environment.

3.23 *Measurement operations for the supra-information system*

If supra-system information processing occurs, then the value and its accompanying variable become data (polynomial terms) in mathematical operations.

The result of statistical operations performed on numerical measurement values is the production of additional numerical values.

3.23.1 Utilization and/or calculation

The output of a measurement may be useful in itself, or it may have statistical calculations carried out on it to increase the amount of information available.

The two most important and common statistical calculations are:

1. **Averaging** to determine the arithmetic mean.
2. **The standard deviation** for a set of numbers. The standard deviation of a set of measurements is an indication of how much the measurements vary from their average value. The standard deviation is the 'root mean square' of the deviations.

The following procedure will provide the standard deviation (root mean square) of a set of numbers:

1. Square all the deviations from the mean.
2. Add them together.
3. Divide by the number of measurements.
4. Determine the square root.

3.23.2 Validation and Verification

Validation is defined in ISO 9000 section 3.8.5 as:

- Confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled.

Validation ensures measuring processes are aligned. Validation is the process of determining whether functional and/or performance requirements are met.

Validation has a secondary meaning; it also means ensuring that whatever is verified or calibrated is fit for the intended use. Hence, systems can be validated, measurements can be validated, and tools can be validated for intended uses.

Here, measurement validation leads to either a verified or refuted initial measurement(s):

1. Verification of the previous measurement.
2. Contradiction of the previous measurement -- discover that there is a different measurement available.

Verification means verifying something, such as repeating a measurement process or using another method to check that the results are aligned with what was previously measured.

Note here that there is no need to encode the concept of defense, and hence, there is either verification or contradiction, and not, verification or refutation. Refutation comes from the encoding of defense, and contradiction is simply logical incompatibility.

3.24 *The method of measurement*

Measurement involves processes, which are also known in some applications as methods. As a method, measurement involves the acquisition of [quantity value] information about the properties of objects (or events); and hence, about a larger and more simplex reality.

There are many measurement methods, because existence can be categorized and inquired into in many ways. For different scientific disciplines, there are different methods. For example, the thermoelectric effect is a measurement method of two meanings: temperature, and the infrared spectroscopy of molecular concentration.

> **TERMINOLOGY:** *A '***reference measurement procedure***' is a process accepted as providing measurement results that fit for their intended use.*

3.25 *Measurement as "an approach"*

Measurement is a set of operations having the object of determining a value of a measurement result, for a given attribute of an entity, using a measurement approach. A measurement approach is a sequence of operations aimed at determining the value of a measurement result. A measurement approach is either:

1. A measurement method,
2. A measurement function, or
3. An analysis model.

3.26 Methodical measurement categorization

Measurement is/involves a system that processes information to answer a question or otherwise determine a relational value. Herein, there are various ways/modes of categorizing the process by which information about an unknown is acquired.

3.26.1 Measurement categorized by the number of [standard] conversions

There are three modes (methods) of measurement, categorically separated based upon the number of conversions present. A "conversion" refers to a 'signal conversion', whereupon a signal from one source is converted by a system into another signal readable by another system (in a network of signal conversion systems). Here, the signal represents information (that may be useful in our fulfillment) about a surrounding real world.

1. **Primary measurement (direct method, no conversions)** – direct observation and comparison. Does not involve a conversion. For example, compare a length of something along a measuring meter stick, and record the observation.
2. **Secondary measurement (1 conversion indirect method)** – involvement of one conversion. For example, the measurement of a thermometer by someone -- a thermometer changes in relationship to its environment (1st conversion), and then, the observer reads the thermometer. Here, the physical system sends a signal to the thermometer (1st conversion), and the thermometer sends a secondary signal to the conscious observer.
3. **Tertiary measurement (2 conversion indirect method)** – involvement of two conversions. For example, the measurement of a rotating shaft by someone using an electronic display -- a rotating shaft changes in relationship to its environment (signal output), whereupon an electromagnetic system perceives the rotations (1st conversion). The electromagnetic system then outputs the reading as a (2nd) signal to a digital display (2nd conversion). From there, a conscious observer perceives the digital measurement of the rotating shaft.

3.26.2 Measurement categorized by type of comparison

There are two principal methods of measurement; one which involves humans, and one which does not involve humans (or, at least, human involvement is superfluous to the observation and value determination). When a human's sensory system is involved in the comparison (measurement), then the method is known as direct. When human's sensory system is not involved, it is known as indirect.

1. **Direct (human sensation)** – A unknown quantity is visually compared, directly with another of the same pattern. Human senses are necessary for measurement. Here, results are obtained from direct comparison. Because a human is involved, the results are not always accurate.
2. **Indirect (no direct human involvement)** – An unknown magnitude is measured by an instrument with a referentially standardized procedure. The indirect method consists of a chain of [a] synchronously connected devices, which form a measuring instrumentation system. This system generally consists of a detector element to detect, a transducer to transduce, and a memory database unit to indicate or record the processed signal. This system is as accurate as its design and application, and may or may not involve human effort

3.26.3 Measurement categorized by proximity

There are two types of measurement method categorized by contact proximity between the measurement instrument and the thing being measured.

1. With physical contact – instrument is placed in direct physical (less than 1mm) contact with the object. The sensing element is known as the sensory. Here, contact is generally molecular.
2. Without physical contact – instrument is not placed in direct physical contact (less than 1mm) with the object. The sensing element is known as the sensory. Here, "contact" is generally electromagnetic.

3.26.4 Measurement categorized by method sub-type

There are many possible measurement method sub-types, including but not limited to the following:

1. **Absolute/fundamental** –the measurements of base quantities enter into the definition of the quantity being measured.
2. **Comparative** – comparison of the value of a quantity to be measured with a known value of the

same quantity.
3. **Null measurement** – the difference between the measurand value and the known value of the same quantity with which it is compared is brought to zero.
4. **Substitution method** – the quantity to be measured is replaced by a known value of the same quantity, so selected that the effects produced in the indicating device by these two values are the same (a type of direct comparison).
5. **Complementary method** – the value of a quantity to be measured is combined with a known value of the same quantity.
6. **Transposition** – the value of the quantity to be measured is first balanced by an initial known value, and then, balanced by another new known value.
7. **Coincidence** – measurements coincide with certain lines and signals.
8. **Deflection** – the value of the quantity to be measured is directly indicated by the deflection of a pointer on a calibrated scale.

3.27 A measurement system

INSIGHT: *A measurement systems indicates the condition of the environment; whereby informed decisions are taken.*

Measurement systems display and/or record an output quantified according (corresponding) to the variable input quantity. The input to the measurement system is the true value of the variable; the system output is the measured value of the variable. Therein, the measurement process may be viewed as a sub-system that generates and outputs information. A measurement system becomes a collection of procedures, gages and operators that are used to obtain measurements.

The function of a measurement system is to provide accurate information about the relative quantity value of a measurand.

The output/result of the interaction between a measuring system and its measured quantity (measurand) is generally termed an 'indication' (expressed with a value, the number part, and a unit, the unifying categorical reference part, forming a mathematical term upon which further statistical calculation can be performed).

In an ideal measurement system, the measured value would be equal to the true value. Here, the accuracy of a measurement system can be defined as the closeness of the measured value to the true value. A perfectly accurate system is a theoretical ideal and the accuracy of a real system is quantified using measurement system error E, where

1. E = measured value − true value
2. E = system output − system input

3.28 System of measurement

A 'system of measurement' includes a collection of 'units of measurement' and rules (logic) relating them to each other.
A system of measurement is a set of related measures that are used to give a numeric value to something.

A system of related measures that facilitates the quantification of some particular characteristic

A "system of measurement" is also known as a "metric" (which is confusing because the system of measurement used as an international standard is called, "the metric system"). There are many systems of measurement, and the metric system is one of those many.

Systems of measurement can be applied describe physical and conceptual systems. Some systems of measurement describe physical systems. Other systems of measurement describe conceptual systems.

A 'system of measurement' involves:

1. A group of 'units of measurement'.
2. The rules relating them to each other.

Systems of measurement are important for the coherent sensing, communication, and construction of systems in the real world.

3.28.1 The metric system of measurement

The International Metric System is an absolute system. Its basic units are the meter, kilogram, and second. It is called an MKS system.

3.29 Elemental composition of a measurement systems

In some cases, the measurement system is made up of only a single component, which gives an output (signal) according to the magnitude of the variable applied to it. However, in most cases, a measurement system is made up of several ordered elements (sub-systems or blocks) between which a signal passes.

It is possible to identify the following types of element (in order), although in a given system one type of element may be missing or may occur more than once:

1. **Transducer (sensing element)** – The element and/or sub-system in contact with the [phenomenological] process, whose output depends in some way on the variable to be measured. Functionally, a transducer is a device that converts a difficult to measure property into a more easily measured property. The transducer often comes into contact with the measured input. A transducer is sometimes referred to as

the sensing element. A sensing element is also known as a transducer (sensor). If there is more than one sensing element in a system, the element in contact with the process is termed the primary sensing element, the others are secondary sensing elements. When digital technology is present, generally, the sensing element transduces the input physical effect (input signal) into another physical output, an electrical output signal(s).
   A. The primary sensing element:
      1. Quantity under measurement makes [first] contact with a primary sensing element.
      2. The condition, state or value of the process variable is sensed, by extracting a small part of energy from the measurand.
      3. This element produces an output which maps to (or otherwise, reflects) the condition, state or value of the measurand.
2. **Signal conditioning element** – The element and/or sub-system that takes the output of the sensing element and converts it into a form[at] more suitable for further processing. In most cases, the output of the sensor or the element quantity to be measured is so "small" in signal magnitude that it is not suitable for the output presentation element. The signal conditioning element converts the signal into a form matching the characteristics of the output device (or more suitable for further processing). Common electrical operations performed on the signal here include, but are not limited to: bridging; amplification; oscillation change; and filtration.
3. **Signal processing/conversion element** – The element and/or sub-system that takes the output of the conditioning element and converts it into a form more suitable for presentation. Here, typical calculations are: computational; integrational; and correctional. This is a digital, not analog, process.
   A. Variable conversion (transducer) element:
      1. Map ("convert") one physical form into another form [of signal] without changing the information content (meaning) of the signal.
      2. There may be multiple conversions.
   B. Variable modification element:
      1. Modifies the signal by amplification, filtration, or other means so that a desired output is produced according to some mathematical rule.
   C. Data processing element:
      1. Modifies the data before it is displayed or finally recorded.
      2. Performs mathematical operations: To calculate average, statistical, and logarithmic values. To convert data into desired form. To separate undesired signal from noise. To provide correction on the output signal.
4. **Signal utilization element** – The element and/or sub-system that displays the signal to an observer, records the signal, and/or uses the signal as input into a functional control system.
5. **Data presentation element** – The element and/or sub-system that presents the measured value in a form which can be easily recognized by an observer. Common examples of these are: simple pointer-scale indicator (indicator gauge); chart recorder; alphanumeric display; visual display unit; and virtual simulation.
   A. Provides a record or indication of the output.
   B. Transmitting information (measured quantity) - to another location or device.
   C. Signaling – to give a signal that the pre-defined value has been reached.
   D. Recording – to produce a continuous record of measured quantity.
   E. Indicating – to indicate the specific value on a calibrated scale.
6. **Data transmission element** – The system, sub-system, or element, that transmits the signal from one location to another without changing its information contents.

3.30 Instrumentation

Tooling is the automation of the process of measurement capture and computation, and it is desirable if efficiency and optimization is valued. An instrument is a device that transforms a physical variable of interest (the measurand) into a form that is suitable for recording (the measurement).

When using an instrument to take observations of a variable, it is essential to apply/encode the following:

- Validity, unbiasedness, and reliability

Measurement instruments have three primary functional elements:

1. **The detector/sensor** – detects and responds to measurement.
2. **The transducer** – converts measurand to an easier to measure property.
3. **The signal conditioner** – modifies signal.
4. **The readout** – displays result.

3.30.1 Instrumentation reading quality

The following terms are used to describe the quality of an instruments reading:

1. **Range** – The region between the limits within which

a quantity is measured, received or transmitted expressed by starting the lower and upper range values.
2. **Span** – The algebraic difference between the upper and lower range values.
3. **Measured variable (a.k.a., measurand)** – a quantity, property or condition that is measured.
4. **Accuracy** – indicates the deviation of the reading from a known value. Accuracy is typically expressed as:
   A. Percentage of full scale reading (upper range value).
   B. Percentage of span.
   C. Percentage of actual reading.
5. **Uncertainty** – Uncertainty of measurement is the doubt that exists about the result of any measurement. Uncertainty is important to make good quality measurements and to understand the results. It is also important in calibration.

3.30.1 Instrumentation systems

An instrument is a device for determining the value or magnitude of a quantity or variable. An instrumentation system is an assembly of various instruments and/or components interconnected to measure, analyze and control various physical quantities (variables). The purpose of an instrumentation (measurement) system is to present an observer with a numerical value corresponding to the variable being measured.

Applications of measurement systems include, but are not limited to:

1. **Monitoring of processes and operations** – measurement systems display and/or record data.
2. **Control of processes and operations** – control systems use measurement data to adjust functioning.
3. **Experimental analysis for science** – science involves the usage of measurement data to evolve/advance.

When action is taken based on measurement, then the measurement serves a [system] control function. Note that a control system that automatically controls its own functioning based upon its own measurements, is known as, an automatic control system.

Here, there are two principal categories of operation (or processing):

1. **Closed-loop systems (a.k.a., a feedback control system)** – A control system that uses the concept of an open loop system as its forward path, but has one or more feedback loops (hence its name) or paths between its output and its input. The control system measures the value of the parameter being controlled at the output of the system, and compares it to a desired signal, then adjusts its functioning if required. This is also known as an automatic feedback control system, or cybernetic/cybernated system.
2. **Open-loop systems** - To control the variable, it is first necessary to measure it. Here, an environmental signal enters a controller. The controller is required to:
   - Compare the output variable with the desired value of the controlled variable, and
   - React by sending a message to the control element to take corrective action.

To solve engineering problems two general methods are available: theoretical and experimental. Many problems require the application of both methods. Types of experimental-analysis problems include, but are not limited to:

1. Study of phenomena with intention of developing a theory.
2. Testing the validity of theoretical predictions.
3. Formulation of generalized empirical relationships.
4. Determination of material, component, and system composition.
5. Determination of material, component, and system parameters, variables, and performance indices/metrics.
6. Solutions to mathematical equations by means of analogies.

In concern to scale, there are two primary types of instrumentation (signal measurement) scaling system:

1. **Absolute systems** – generate and/or measure an absolute signal (e.g., the position).
2. **Incremental system** – counts the number of steps between positions.
3. **Pure** – the number of steps between the start of the system and now is provided.
4. **Referential** – there is a reference, where a reference position is aligned with upon increment of the scale.

The clock is an absolute measurement system, it allows consciousness to determine a point in time. A stop watch is an incremental system, it allows consciousness to determine how many seconds (increments of 'time') have occurred ("gone by") since the start of the measurement.

3.30.2 Sensor / Measuring instrument

A measuring system may consist of only one measuring instrument. A measuring system is one or more (a set of) sensors distributed in space, and an integrated means for data processing information from the sensor with a set of pre-existing, and pre-structured information.

A measuring system must include the following:

1. **Sensor** - A sensor is an element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a quantity to be measured. A sensor is the sensitive element in a measuring system. In practice this term is also applied for designating the device that:
   A. Includes a group of sensitive elements (e.g. an array);
   B. Consists of a number of separate transducers, connected in series (e.g. a primary transducer and amplifier);
   C. Contains a) and b) + additional signal processing units (analogue-to-digital converter, interface, microcontroller, and indicator in any combination).
2. **Intelligent sensor (a.k.a., smart sensor)** - sensors which are able to:
   A. Realize automatic switching of a sub-range of measurements,
   B. Introduce corrections depending on a change of influence quantity,
   C. Carry out automatic self-check of metrological serviceability (a self-validating, adaptive, self-checking, self-diagnosing, self-calibrating, fault-tolerant sensor).

It is possible to describe the measuring system consisting of one sensor (item c) of the list). The sensor may contain a number of sensors according to item b) of the list, each of them containing a group of sensors according to item a) and each sensor of the last group containing a group of sensors according to the VIM-3 definition.

Sensor types include, bit are not limited to:

1. **Multisensor** - A group of sensors perceiving the same physical quantity (an analog: the tip of the tongue.
2. **Polysensor** - A group of sensors perceiving various physical quantities (an analog: a surface of the tongue as a whole).

Sensors are often transducers in that they are devices that convert input energy of one form into output energy of another form.

Sensors can be categorized into two broad classes depending on how they interact with the environment they are measuring.

1. **Passive sensors** do not add energy as part of the measurement process but may remove energy in their operation.
2. **Active sensors** add energy to the measurement environment as part of the measurement process.

Sensory fusion is a process where two or more sensors are used to observe the environment and their output signals are combined in some manner (typically in a processor) provide a single enhanced measurement. This process frequently allows measurement of phenomena that would otherwise be unobservable.

> **NOTE:** *Biological sensor systems enable determining a value of a "measurand", and moreover, evaluating the distribution of the "measurand" in a multiparameter field and forming a "multiparameter image".*

> **INSIGHT:** *The ultimate purpose of intelligence is to ensure the survival of its carrier.*

3.30.3 Measurement system sensor types

Measurement systems sensors may be divided into three categories of guidance.

1. **Direct [guidance]** – wire guidance, magnetic guidance. These are the most reliable. These systems suffer from the considerable problem of path planning. If the path has to be changed, a certain number of hours are required to install the cable inside the floor and the guidance system must be stopped during installation.
2. **Relative [guidance]** - The relative or dead-reckoning methods, such as encoders, gyroscopes, ultrasound, etc., have the considerable advantage of being totally self-contained inside the system, relatively simple to use and able to guarantee a high data rate. However, since these systems integrate relative increments, errors grow considerably over time.
3. **Absolute [guidance]** - use of external references to achieve an absolute measurement with respect to the environment in which the system exists. These systems are more complicated than the relative ones, work at a slower rate, and lead to the problem of the visibility of the targets needed during the systems' path through an environment. Generally, since these measure the system's position and attitude with respect to absolute references (targets), the error is always bounded and absolute repeatability guaranteed.
4. **Combination** – a combination of the three types.

From the above considerations it is clear why many systems currently make use of both a relative and an absolute system.

3.31 Measuring devices, instruments, and tools

Sensors observe, sense, and otherwise, interact with the environment. Sensors observe stimulus, producing an "observation" of a property(s), such as time, location, and distance. And, this observation allows for interactive change with the environment generating or otherwise relating to a stimulus.

A measuring instrument is a device used for making measurements alone or in conjunction with one or more supplementary devices (as part of measuring system). A measuring instrument (gauge) is frequently a form of transducer. A transducer is a device that provides an output quantity (most often an electric current) having a specific relation with an input quantity (most often a physio-logic signal). The physiologic signal is collected by a sensor defined as an element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a quantity to be measured, or less frequently, by a detector defined as a device or substance that indicates the presence of a phenomenon, body, or substance when a threshold value of an associated quantity is exceeded.

3.32 Properties of measuring devices

Measuring instruments provide a quantity value for the measurand. Therein, the measuring 'interval' or measuring 'range' is the set of values of quantities of the same kind that can be measured by a given instrument with specified instrumental uncertainty under defined conditions. A measuring instrument/system is characterized by [at least] the following properties or quality criteria:

1. **Sensitivity** - the minimum change in input signal to which an instrument can respond. Sensitivity is the ratio of o/p response to a specific range in i/p.
2. **Selectivity** – is a property used with a specified measurement procedure, whereby it provides measured quantity values for one or more measurands, such that the values of each measurand are independent of other measurands, or other quantities in the phenomenon, body, or substance being investigated.
3. **Resolution** - is the smallest change in a quantity being measured that causes a perceptible change in the corresponding output of the measuring instrument.
4. **Stability** - is the property of a measuring instrument, whereby its metrological properties remain constant in time. An instrumental drift is the continuous or incremental change over time of the indication because of change in metrological properties.
5. **Step response time** - is the duration between the instant when an input quantity value of a measuring instrument is subjected to an abrupt change between 2 specified constant quantity values and the instant when a corresponding device output settles within specified limits around its final steady value.
6. **Maximum permissible measurement error or limits of error** - the boundary value of measurement error, with respect to a known reference quantity value, permitted by specifications for a given measurement, measuring instrument, or measuring system. The term 'tolerance', which is the magnitude of permissible variation of a quantity, should not be used to designate the maximum permissible error. Tolerance includes the true value ± the maximum permissible error.

Strictly speaking, accuracy, trueness, and precision are qualifying measurements, whereas sensitivity, selectivity, resolution, stability, and step response time are qualifying dynamic outputs of devices.

> **NOTE:** *The dynamic output of a measuring instrument is sometimes known as an 'indication'.*

3.33 Measurement performance characteristics (i.e., measurement output parameters)

Measurement generally occurs through instrumentation. That instrument has a set of output/performance characteristics.

3.33.3.1 Static performance characteristics

Static performance characteristics include principally, that desired input to the instrument not change in relation to time. Therein, the following sub-conceptualizations are required:

- Error, accuracy, calibration, hysteresis, dead zone, drift, sensitivity, threshold, resolution, precision, repeatability, reproducibility, linearity, etc.

3.33.3.2 Dynamic performance characteristics

Dynamic performance characteristics include, but are not limited to: speed of response, measuring lag, fidelity, frequency response, dynamic error, overshoot, dead time and dead zone.

Therein,

1. **Readability** indicates the closeness with which the scale of the instrument may be read.

2. **Least count** is the smallest difference between two indications that can be detected on the instrument scale.
3. **Range** represents the highest possible value that can be measured by an instrument, or limits within which the instrument is designed to operate
4. **Linearity** is a measurement system category; wherein, a measurement system is linear if the output is linear proportional to the input.
5. **Repeatability** is the ability of a measuring system to repeat output readings when the same input is applied to it consecutively, under the same conditions and in the same direction. Repeatability is expressed as the maximum difference between output readings.
6. **Reproducibility** is the degree of closeness with which the same value of a variable may be measured at different times.
7. **System response** is the ability of the system to transmit and present all the relevant information contained in the input signal.
8. **Threshold** is the minimum value of a ratio (e.g., i/p or a/b) required to cause a detectable change [from 0(zero)], o/p.
9. **Hysteresis** is the maximum differences in two output (indicated values) at same input (measurand) value within the specified range when input is continuously increased from zero and when input is continuously decreased for maximum value.

3.34 Measurement uncertainty and error

Error is the difference between the measured value and the 'true value' of the thing being measured. Uncertainty is a quantification of the doubt about the measurement result. Here, the accuracy of an instrument is defined as the difference between the true value of the measurand and the measured value indicated by the instrument. Typically, the true value is defined in reference to some absolute or agreed upon standard.

A measure (attribute) is "well-defined" if scale and unit are clearly specified; specification of the unit and scale ensures the measure is unambiguous.

3.34.3.1 Measurement accuracy

Measurement accuracy is the closeness of agreement between a measured quantity value and a true quantity value of the measurand. The concept of accuracy is a quality and is not given a numerical value. A measurement is said to be more accurate when it offers a smaller measurement error. Therefore, a measurement error is qualifying a single measurement.

3.34.3.2 Measurement trueness

Measurement trueness is the closeness of agreement between the average of an infinite number of replicate measured quantity values and the true or a reference quantity value. The concept trueness is a quality and is not given a numerical value. Measurement trueness is inversely related to systematic measurement error but not to random measurement error. Since the mean random error is zero, the bias (average of measured value – reference value) is an estimate of the systematic measurement error. The traditional averaging of (measured value – reference value) is equivalent to the former formula only when there is a unique true (or reference) value. When there are different quantities of the measurand, the bias can be fixed, proportional, or distributed following specific functions. Since a systematic error cannot be normally/randomly distributed, averaging (measured value – reference value) is therefore an approximate representation of the averaged bias (systematic error).

3.34.3.3 Measurement precision

Measurement precision is the closeness of agreement between measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions. Measurement precision is related to random measurement error and usually expressed numerically by measures of imprecision, such as standard deviation (σ), variance (σ2), or coefficient of variation (σ/mean) and assuming a mean = zero.

3.34.3.4 Measurement error

Measurement error. We have seen in "Measurement Accuracy" that it is the difference between a unique measured quantity value and a reference quantity value. The measurement error can be systematic (bias) qualifying the untrueness (i.e., "measurement trueness") or random qualifying the imprecision (i.e., "measurement precision"). When the term "measurement error" is used without further information, it combines systematic and random errors and qualifies the inaccuracy.

- % error = |experimental-accepted| x 100 / accepted value

For any particular measurement there will be some error due to systematic (bias) and random (noise) error sources. The combination of systematic and random error can be visualized by considering the analogy of the target.

There are three classifications of measurement error:

1. **Gross errors or mistakes**
   A. **Accidents and mistakes** – can avoid only by staying focused (and in flow).
2. **Systematic error sources (bias)** – these have definite magnitude and direction.
   A. **Instrument error** – the instrument's design, maintenance, selection, calibration, and/or

operation-usage cause an error.

B. **Environment error** – due to conditions external to the measuring instrumentation sub-system. Use the instrument under the conditions (parameters) it was designed and calibrated for. Calibrate for local conditions.
C. **Observation error** – error due to poor capabilities and/or motivations of operator.
D. **Operational error** – misuse of the instrument or poor operational technique.
E. **System interaction error** – an interaction error may occur between a system (to be measured) and the direct point of contact with the instrument's body. The contact could change the condition of the measuring instrumentation system. For example, a ruler pressed against a body (system) resulting in the deformation of the body and a reading with a large error.

3. **Random error sources (noise)**
    A. If systematic errors can be removed from a measurement, some error will remain due to the random error sources that define the precision of the measurement. Random error is sometimes referred to as noise, which is defined as a signal that carries no useful information.
    B. Presently uncategorizable errors.

3.34.3.5 Stability and consistency

All measurements have to exhibit two basic characteristics: stability and consistency. To the degree that they do, they are called, "reliable measures".

1. **Stability** - A stable measure will yield identical measurement results whenever it encounters an identical amount of the theoretical concept.
2. **Reliability** – An operational definition describing a measurement procedure which behaves in a consistent fashion.
3. **Validity** - The amount of measurement validity cannot be determined by any numerical method. It relies on a self-evident overlap between "verbal world" theoretical definitions and "measurement world" operational definitions. Furthermore, the self-evident overlap must be generally agreed upon by independent observers. It is not enough that an operational definition shows measurement validity to the researcher who constructs it; it must also exhibit the same measurement validity to other researchers and critics.
    A. Concurrent validity
    B. Discriminant validity
    C. Construct validity

3.34.3.6 Measurement uncertainty

Measurement uncertainty is a parameter characterizing the dispersion of the quantity values being attributed to a measurand based on the information used. This concept is broader than precision including uncertainty due to time drift, definitional uncertainty, and other uncertainties. There are 2 types of evaluation of the uncertainty of measurements: type A based on statistical analysis of measured values and type B based on other means such as certified references, authoritative published values, or personal experience.

3.34.3.7 Error triangulation

This process of combining information from multiple sources to arrive at a true or at least more accurate value is called triangulation, a loose analogy to the process in geometry of determining the location of a point in terms of its relationship to two other known points. The key idea behind triangulation is that, although a single measurement of a concept might contain too much error (of either known or unknown types) to be either reliable or valid by itself, by combining information from several types of measurements, at least some of whose characteristics are already known, we can arrive at an acceptable measurement of the unknown quantity. We expect that each measurement contains error, but we hope it does not include the same type of error, so that through multiple types of measurement, we can get a reasonable estimate of the quantity or quality of interest.

3.35 Categorization and classification

Categorization and classification mean essentially the same thing (the process is also sometimes called "division") – the delineation of discreteness of variables. Discreteness of variables is a key part of evaluation and the naming of variables for quantitative research/measurement. This delineation results in an organized structuring of information based upon inter-relationships.

> **NOTE:** *Classification can only occur on similar items (i.e., items expressing a similar pattern).*

In general parlance, however, the words categorization and classification have slightly different definitions:

1. In general parlance, **categorization** is a systematic method of modeling using related conceptual nodes. Every node in the model/map represents a concept, and sub-/supra-nodes represents a more specific/more general concept.
2. In general parlance, **classification** is the representation of knowledge (or awareness) by discrete organization.

Regardless, terms mean the use of concepts (and sub-/supra-concepts) to formalize a difference or similarity (a delineation or division).

> **INSIGHT:** *How someone categorizes and*

the results of that categorization will affect someone's thinking, and consequently, their motivations and behaviors.

Therein, a category or class is a collection of similar objects or entities, which are dissimilar from other objects or entities [of a different category or class]. From the perspective of unification, those other categories/classes may exist:

1. At the same level in a leveled/tiered arrangement of categories/classes.
2. At different levels in a leveled/tiered arrangement of categories/classes.

Suffix: -ization and -ication mean "the act of".

1. **Classification** – act[ion] of classifying – identifying similar and different classes.
2. **Categorization** – act[ion] of categorizing – identifying similar and different categories.

The nodes (concepts) in the organized structure are called by different names, including but not limited to: class, type, set, or taxon, and to a lesser degree of usage, unit, topic, and subject.

In other words,

1. Each node in a classification structure is called a class.
2. Each node in a categorization structure is called a category.

The supra- and sub-nodes (supra-/sub-concepts) in a categorization or classification structure (scheme) may be said to exist on different levels or ranks. Rank is the relative level of a group of classified objects/events. A given rank subsumes under it less general categories, that is, more specific descriptions. Above it, each rank is classified within more general categories. Therein,

1. Each level "down" in the structure zooms in on a smaller and smaller physical/conceptual area.
2. Each level "up" in the structure zooms in on the larger physical/conceptual area.

NOTE: *All measurement data is categorical data. Categorical data is data that can be organized into mutually exclusive categories. Given the presence of categorical information, quantitative and qualitative data may also be considered categorical data.*

3.36 *Classification operations*

In order to classify/categorize, the following classificatory operations (classification operations) must be performed:

1. Conceptualization operation (defining, identifying terminological and definitional classes/types/categories) – ensuring that concepts (classes or types) have clear, logical, and delineated/bounded definitions. Concepts must be clarified and denominated by a "suitable" (linguistically precise) term or expression. If there is a hierarchy, then concepts "higher up" the hierarchy represent greater unification. Concepts corresponding to individual classes are either formed or clarified by the definition of their boundaries with contiguous concepts.
2. Conceptual analysis operation (divisioning, conceptual elaboration) - the extension of a concept [at a given level of generality] is subdivided into several (two or more) narrower extensions corresponding to as many concepts at lower level of generality; this subdivision is obtained by stating that an aspect of each of the latter concepts is a different partial articulation of the corresponding aspect of the higher concept. Notice that in principle all other aspects of the higher concept are carried into each of the lower concepts. This is a process of conceptual elaboration.
3. Pattern recognition operation (grouping) - the objects or events of a given set are grouped into two or more subsets according to the perceived similarities of their states on one or (more frequently) several properties; subsets may be successively grouped into subsets of wider extension and higher hierarchical level.
4. Assignment operation (assigning, classing, assigning to a class/type) - whereby objects or events are assigned to classes or types which have been previously defined. This is the assignment of objects/events to classes, types or taxa which have been previously defined.

These classification operations produce a classification (categorization) structure that organizes related information by named relationships. That organized information may be viewed as a model/map and used for creating in the world. The input of additional related information becomes organized according to the classification model (which may be known as an ontology, taxonomy, or typology), and its integration may change may change the model (if defining, divisioning, and grouping continue during the assigning process).

3.36.1 Combinatorics

In order to combine parts (or elements) into a whole, a series of processes (process functions) must occur. The three primary functional process to combing parts are:

1. Labeling

2. Selecting
3. Grouping [given all information is known].

3.37 Classification/categorization output: Ontology, taxonomy, or typology, or typology

The result of categorization/classification is an organizational structure known as an ontology, taxonomy, or typology. In common usage, the words typology, taxonomy, and ontology mean essentially the same thing - the categorization/classification of something (or things) and its (their) resulting structurally organized output as an information system (model/map). They are different words used by different disciplines that mean essentially the same thing. In some disciplines, the term ontology is used to imply a broader scope of categorized information about reality and the nature of existence. In other disciples and contexts, the word taxonomy or typology is used.

When ontology and taxonomy are used in the same context, but to mean different things, then the term ontology is likely being used to encompass a number of taxonomies, with each taxonomy organizing a concept/subject/topic in a particular way.

In their disciplined application, the terms have different originations and a slight variance of definition, but still mean the same thing – a structural organization of those objects/entities which have undergone categorization/classification:

1. The word "**ontology**" comes from philosophy, and is a series of categorized characterizations of the nature of being, or reality. Philosophically speaking, it is intended to be a systematic account of existence. Ontologies are concept specifications and relations about reality. The term ontology means the science or study of being and the nature of existence. Etymologically, the word "ontology" comes from modern latin, ontologia (c. 1600), from onto- + -logy. Onto- means "a being, individual; being, existence.
2. The word "**taxonomy**" means the science of classification. The word was neologized ("coined") by someone studying botany. Etymologically, the word "taxonomy" comes from French taxonomie (1813), coined irregularly from Greek taxis "arrangement" + -nomia "method," from -nomos "managing," from nemein "to manage". The word has come to mean the science of defining groups on the basis of shared characteristics, and giving names to those groups. It is the classification of existence according to characteristics; it is the science of organizing existence into a system of different groups according to the features that they share, and of giving them names. In other words, a taxonomy is a method of partitioning (with purposeful and identified parameters) and giving names.
   A. A taxonomy is a semantic hierarchy in which information entities are related by either the subclassification of relation or the subclass of relation. Note: subclassification is semantically weaker than subclass of relation. A taxonomy is a form of classification scheme. Designed to group related things together. It is a hierarchical thesaurus with terms applied at the final node. It is a tangible hierarchy forming a structure of information related to a root or axiomatic conception. It expresses similar relationships between things. It is an information model. A taxonomy is a knowledge organization system. It is a hierarchy of relationships. It is a hierarchy of related types.
   B. The dimensions of a taxonomy represent empirically observable and measurable characteristics. It is a classification structure based on the empirical/operational.
   C. Each node in a taxonomy may be called a taxon (plural, taxa).
   D. A taxonomy is:
   E. Organized into a hierarchy.
   F. Each tag is unique.
   G. The tags relate to one another logically, and preferentially relate to the existent, which they are classifying.
   H. A structure for organizing incoming information.
3. The word "typology" means the study of types (e.g., types of systems, for example, biological, chemical, linguistical, architectural, etc.) It refers to the science of classifying existence. The study or system of dividing a large group into smaller groups according to similar features, qualities, and characteristics. Typology involves the process of partitioning (based on identified parameters) for the purpose of study. Working with typologies contributes decisively to forming concepts, exploring dimensionality, establishing measurement categories, and grouping cases.
   A. The dimensions of a typology represent concepts rather than empirical classes. It is a classification structure based on the abstract (i.e., the conceptual).
   B. Each node in a typology is called a type.
   C. Typification – act[ion] of typifying – identifying similar and different types.

In computer science, what "exists" is what is represented. Hence, programmatically speaking, ontologies/taxonomies/typologies represent explicit domain conceptual specifications -- an ontology/taxonomy/typology is a domain of interest's formal, explicit specification of a shared conceptualization. Thus, ontologies/taxonomies ensure a shared conceptualizations formal specification.

> **NOTE:** *Tabulation is the logical operation of [numerically] counting the number of cases that fall into each category.*

3.38 Real world category continuity

Real world categories differ in their range and level of continuity. For example, members of the category "atomic element" are highly similar (having atoms, electrons, and protons), and thus, have a relatively small category range and are fairly cohesive (i.e., highly continuous). On the other hand, the category "weapon" is highly variable and contains items such as knives, bombs, guns, etc., which are highly discontinuous.

3.39 Qualitative data type classification

Qualitative data can be nominal and ordinal, but not interval or ratio. Qualitative data cannot be continuous. Discrete, quantitative counts must be ratio. Therein, there are five different possibilities, which forms the following taxanomical concept map:

1. **Categories**: Qualitative, discrete, nominal data (such as colors, names, or labels).
2. **Ranks**: Qualitative, discrete, ordinal data (such as sizes, preferences, or grades).
3. **Counts**: Quantitative, discrete, ratio data that count something.
4. **Relative (or Relative Scale) Measures**: Quantitative, continuous, interval data (such as temperatures).
5. **Absolute (or Absolute Scale) Measures**: Quantitative, continuous, ratio data (such as heights and weights).

3.40 The conceptual components of a measurement system

The measurement of a property [of a bounded existence] may be categorized according to the following sub-concepts (i.e., "criteria"). For a measurement to represent an unambiguous comparison, all four conceptual criteria must have accurate information. The measurement of an attribute (property) of a real world system requires the following conceptual information:

1. Typological/taxonomical positioning (level/scale of measurement): The type or level of measurement is a taxonomy (classification) for the methodological character of a comparison. In other words, the data collected on a variable, and accompanying data, fit into one of several taxonomical scale (or scaling) categories, which determine the methods (and operations) that may be used in its [mathematical-statistical] processing.
2. Numerical quantity (magnitude determination): The magnitude or [numerical] quantity is the numerical value of the characterization, usually obtained with a suitably chosen measuring instrument (a referencing process or tool). A numerical value is a real number that represents a quantity.
3. Unit (referential unit system): A unit assigns a mathematical weighting factor to the magnitude that is derived as a ratio to the property of an artefact used as a standard or a natural physical quantity. Measurement always includes units - without units, a quantity and its corresponding measurement carry no understanding.
4. Uncertainty (determination): An uncertainty represents the "random" and systemic errors of the measurement procedure; it indicates a confidence level in the measurement. All measurements have some degree of uncertainty associated with them, which is usually expressed as a 'standard error of measurement'. Errors are evaluated by methodically repeating measurements and considering the accuracy and precision of the measuring instrument:
   A. Measurement accuracy - How close a measurement comes to the true value (a.k.a., correct value).
   B. Measurement precision - How close a series of measurements are to one another.
   C. Precision refers to how small an uncertainty the measuring instrument and conditions will provide.

3.40.1 Typological/taxonomical positioning(i.e., levels/scales of measurement)

All measurement data and variables fit into one of several possible levels (or scales) of measure[ment]. Together, the levels/scales form a taxonomy/typology known as a 'level of measurement' or 'scale of measure', which classifies the nature of information assigned to a variable.

In specific, the terms, 'level/scale of measure[ment]', refer to the degree of relationship among the values that are assigned to the attributes for a variable upon which measurement data is being collected and will be processed. Associated with each "level" of measurement is a set of permissible [mathematical] transformations [of the data]. (see illustrator for "level of measurement")

In its expression, a 'level/scale of measure[ment]' is a typology (categorically mapped arrangement of concepts) for defining data processed by measurement operations as part of a variable. Data represented as numbers can be grouped/categorized into 4 types (or levels) known as the levels of measurement (or scales of measure). The levels/scales have an order. Each ascending level possesses the characteristics of the preceding level, plus an additional quality.

In common parlance, the terms 'levels of measurement' and 'scales of measure' convey the same (or highly similar) meaning. However, in practice, the terms 'level of measurement' and 'scale of measurement' may have slightly different meanings:

1. **Level of measurement** refers to the particular way/order [in the taxonomy] that a variable is measured, and
2. **Scale of measurement** refers to the particular tool/process for sorting the data that applies based on the level.

Note that sometimes these levels/scales of measurement are referred to as "levels of measurement scales". Regardless of labeling, the concept refers to the classification/categorization of the type of data it is possible to collect from a variable due to the presence of underlying relationships.

'Level of measurement' or 'scale of measure[ment]' is a classification that describes the nature of information within the numbers assigned to variables. It could also be said that [measurement] scales are distinguished by their level of measurement. There are four levels of measurement.

The most commonly used 'level of measurement' typology has three scales of measurement, and one level of basic categorization:

1. Level 1 (not a scale): Basic categorization/sorting – **nominal categorizing**
   - The initiation of categorization; initiating categorization.
2. Level 2 (1st scale): A one dimensional ordering – **ordinal scaling**
   - Associating an ordering dimension to the categorization.
3. Level 3 (2nd scale): Subdivisioning/delineating the order – **interval scaling**
   - Divisioning the categorical dimension.
4. Level 4 (3rd scale): Affixing/absoluting the order [to a zero point] – **ratio scale**
   - Absoluting the categorization.

Note: *The "list" of available levels/scales [of measurement] is itself an ordinal typology categorization of data complexity.*

There is a [categorical] hierarchy (order) implied in the concept, 'level of measurement'. At lower 'levels' of measurement assumptions tend to be less restrictive and data analyses tend to be less sensitive. At each level up the hierarchy, the current level includes all of the qualities of the one below it and adds something new. In general, it is desirable to have a higher level/scale of measurement (e.g., interval or ratio) rather than a lower one (nominal or ordinal).

Hence, it could be said that measurement data is distinguished by the relationship complexity of the information it carries. All measurements must take one of four (sometime five) forms, also known as "levels of measurement". The four levels of measurement are:

1. **Nominal scale/level (non-metric or categorical)** - lowest level of information. There are only categories (strictly qualitative information). Herein, there is only the assignment of numbers. This is commonly referred to as the "nominal [measurement-level] scale". Note that this scale/level does not represent true measurement.
2. **Ordinal scale/level (non-metric or categorical)** - a higher level of information, ranking scale; it consists of a set of categories that are sequentially ranked-ordered with care to size or magnitude of difference between different variates (quantitative order exists among them). Ranking/ordering of the available numbers by conceptual criteria, but no information is available to derive an understand of how far apart they are separated conceptually and/or numerically. This is commonly referred to as the "ordinal [measurement-level] scale".
3. **Interval (cardinal) scale/level (metric)** - an even higher level of information; interval scale consists of ordered categories with precisely equal intervals between each category. Differences will reflect relative changes in magnitude, but ratios are not meaningful due to the absence of an absolute zero reference point. A scale which represents quantity, and has equal units, but for which zero represents an additional point of measurement is an interval scale. This is commonly referred to as the "interval [measurement-level] scale".
4. **Ratio scale/level (metric)** - the highest level of information. The ratio scale is a specific interval scale that includes an absolute-zero point such that ratios of data do reflect changes in magnitude, precisely. A[n interval] scale that has an absolute zero (no numbers exist below the zero). This is commonly referred to as the "ratio [measurement-level] scale".

Objective measurement scales are otherwise known as numeric measurement scales. The [objective/numeric] scales of measurement are nominal, ordinal, interval, and ratio. These scales represent an order in themselves

-- the scales themselves are a scale of increasingly bound understanding. The ratio (or absolute) scale is the most restrictive of all, and the nominal scale is the least bound (and may not even be considered a scale, because it does not scale along any dimensions). The four scale types are ordered in that all later scales have all the properties of earlier scales— plus additional properties.

Each level of measurement and its corresponding scale is able to measure one or more of the four properties of measurement:

1. Identity (nominal)
2. Magnitude (ordinal)
3. Equal intervals (interval)
4. Minimum value of zero (ratio or absolute)

> **HISTORICAL NOTE:** *These levels and scales of measurement were invented by Stanley Smith Stevens, who wrote about them in a 1946 article in Science, titled "On the Theory of Scales of Measurement."*

All levels of measurement give the ability to determine the presence or absence of some thing. A second level of measurement adds the idea of quantity (e.g., "more of ..." or "higher than ..."), or an underlying dimension, to the measure's ability to detect. If the measurement contains only detection and comparative ordering information, then it is called ordinal. At the next higher level, measurement adds the idea of units, such that absolute statements (rather than comparative) can be given about the similarity or difference between measurements. That is, it is possible to state the number of units by which observations are measured to be different. This level of measurement is called interval. Finally, if the measure is interval, but also contains an absolute zero category or scale point, then it is possible to give statements of proportion ("only one half of") or ratios ("twice as much...") about the magnitude of the measurement. This highest level of measurement is called the ratio-level.

The importance of the measurement level is threefold:

1. It determines the selection of test statistics.
2. It affects the amount of information collected about variables.
3. It affects how questions (inquiries) are formed.

Knowing the level/scale of measurement facilitates decisioning on the interpretation of data from that variable. If a variable is known to be nominal, then it is known that the numerical values are simply short codes for the longer names. Second, knowing the level of measurement facilitates decisioning in concern to what statistical analysis is appropriate on the values that were assigned. The type of scale used in taking measurements directly impinges on the statistical techniques which can legitimately be used in the analysis.

In statistics, different types of data utilize different scales. In other words, not every attribute or variable can be translated to numerical values in the same way.

The nominal scale offers the least statistical information content, and the ratio scale the highest. Nominal and ordinal are non-metric (or categorical) scales; that is, their response values are not directly usable as a numerical value. Interval and ration scales are metric scales that allow for various arithmetic operations.

The level of measurement expresses, how quantifiable a data value actually is (i.e., to what extent mathematical operations can be applied).

Scales [of measurement] with greater complexity, and hence, more categorical data, allow for greater mathematical (logical) processing (analysis and synthesis). In other words, the accurate processing of greater complexity will facilitate greater understanding. A greater number of meaningful operations (data processing) can be done on complex data. This delineation of scales [of measurement] by data complexity is otherwise, and unnecessarily, referred to as levels [of measurement].

The type of measurement scale determines:

- How measurement data is processes.
- Whether statements involving measurement data are meaningful.

> **TERMINOLOGY:** *A continuous scale has units of measurement that are in principle infinitely divisible, so that any particular outcome (continuous variable) could be drawn out to as many points (e.g., decimal places) as practical.*

3.40.2 Scaling

A scale is a conceptual technique to measure some thing. It is an abstract measurement tool for comparing (relating) common attributes of entities. Therein, scaling is the process of ordering a series of items along some type of continuum. A concept, object, or event may be assigned a [measured] number along a scale representing a dimension (or concept). In other words, the data of an observation/sensation is encoded via a rule/principle along a pre-existing comparison continuum known as a [dimensional] scale. A scale is defined as the collection of attributes used to measure a specific [conceptual] variable (e.g., time, temperature, gender, etc.). A scale is a structure for mapping. A particular way of assigning numbers or symbols to measure something is called a scale of measurement (sometimes also called a system of measurement).

> **Clarification:** *In drafting, architecture and engineering, the term scale has two meanings. A scale is a dimension that represents the structure shown in a plan. A scale is also a ruler used in drawing and measuring architectural*

and engineering plans. Hence, the term scale is sometimes used to refer to a measuring instrument, and sometimes even the standard of measurement.

Simply, a scale is a rule (principle) used for the assignment of numerals to properties of objects or events. The concept depicting the rule upon which a scale is based is sometimes called the 'dimension' [of the scale]. This equates a scale to a specific method of measurement. Measurement always occurs in a specific way, which means that every measurement process must have a rule of measurement. Every process of measurement must have a scale of measurement.

Note: *A 'measurement scale' is a set of predefined symbols or values in order to represent certain common measures.*

Visually, a scale is a set of points on a line (or, ordered attributes of a concept) used for measuring (associating objects/events with words and/or numbers in a logical manner so that the data can be processed by a mathematical system.

A 'scale' represents the way a variable is measured or quantified. For example, the variable "gender" is commonly measured on a scale defined by the specific attributes "male" and "female". A scale could be considered a "technique" to measure something and integrate it within a numeric, semantic, or graphical system. These are simply ways to categorize different types of variables.

Scaling is the procedure for the assignment of numbers (or symbols) to a property of events/objects in order to impart some of the characteristics of numbers to the properties in question. It describes the procedure of assigning numbers to concepts – a scale is a continuum, consisting of the highest point and the lowest point. Simply, scaling is the assignment of objects to numbers according to a rule. The objects can be linguistic concepts, or numerical concepts.

Scales are generally divided into two broad categories: unidimensional and multidimensional. A scale can have any number of dimensions in it. What's a dimension? Think of a dimension as a number line. If we want to measure a construct, we have to decide whether the concept can be measured well with one number line or whether it may need more.

NOTE: *Concept mapping is a technique for visualizing scales.*

The scale determines what operations among the numbers assigned in a measurement will yield results significant for what is being measured. In other words, it carries the information for an initial interpretation of the numbers arrived at in a measurement. What mathematical transformations measurement can be subjected to depends on the scale in terms of which they were arrived at. Of course, this depends entirely on the available mathematics. There is no advantage in using a scale that allows operations that are no known how to perform.

Scales are important because they define the nature of information about variables.

A rating scale is an assessment instrument (technique) involving a set of categories designed to elicit information about a quantitative or qualitative attribute (based on pre-determined criteria). Through the use of the rating scale technique, the observer or rater categorizes the objects, events or persons on a continuum represented by a series of continuous concepts or numerals. There are four types of rating scale: nominal; ordinal; interval; and ratio.

Rating scales may be presented in six ways:

1. The graphic rating scale – various points are positioned along a line to form a continuum and the measurement is associated with its compared position along the line.
2. Numerical scale - A numerical scale is a rating scale that is used to measure or identify quantitative data.
3. Graphic scales
4. Percentage rating
5. Standard scales
6. Scales of cumulated points
7. Forced choice scales

3.40.3 Scale traceability

For metric scales the traceability problem is relatively simple -- all measurements have to be related to a single standard. For the qualitative scale types, the traceability problem can be more complicated because more standards are required.

Nominal scales typically have the greatest number of standards associated with them, usually one for each possible category on the scale. The standards may be descriptive or based on artefacts, such as standard reference materials.

Ordinal scales require a minimum of two standards, and in many cases require an approved or specified interpolating instrument.

Many interval scales can be expressed in terms of metric quantities, so the traceability problem is not too difficult. The log-ratio scale, for example, requires a definition of the multiplying constant, which can be defined without error, and a reference value, which in most cases takes the place of the unit on metric scales. All of the time scales (time of day, year, etc.) rely on measurements of time interval (a metric quantity) and an arbitrarily defined zero. Angle scales, such as latitude and longitude, also rely on angle interval and an arbitrary zero.

3.40.4 Evaluation through comparative and non-comparative scaling

In comparative scaling, evaluation involves comparing one thing of a certain type with another thing of the same type against a categorized set of criteria (e.g., one product with a specific function against another product with the same function). With noncomparative scaling, only one product is evaluated against a categorized set of criteria.

3.40.5 Degrees

The points along a scale may be referred to as degrees. A set of degrees (points) creates the scale. Therein, a 'property' of a scale is a 'degree'. A single degree within a scale represents:

1. A sub-delineation (subdivision) of a concept.
2. An iteration of a conceptual pattern.

A degree is a measurement of a whole concept (plane angle), defined so that the whole concept (full rotation) is expressed in the categorically (typologically) sub-divided manner of scales/levels of measurement (e.g., ordinal or interval; 360 degrees). Together, the categorical sub-divisions represent the whole set of possible divisions. For instance, there are 360 of the unit "degree" in the full rotation around a plane angle. A degree is a subdivided point along a conceptual line.

Here, the term 'range' refers to the bounds/endpoints of the concept or system. It represents the range of that which is possible, the range of possible numeric or conceptual values. For instance, the range of common subdivisions chosen for a plane angle (because history, or logic) is 360 (as, the count of 1,2,3,4,...). Hence, the range would be 0 at one boundary and 360 at the other (in a 2-axis/attribute system). Presently, the concept gender, and its relationship to genetic expression has a 2 attribute/characteristic [system]: female and male. In terms of gender, the scale [of measurement] has 2 attributes/degrees, which represent the entire range of possible attributes/degrees.

The range is the mapping of an attribute in the real world to a mathematical system. The mapping itself can be seen as a function behaving according to set of rules

> **NOTE:** *Only information with a value (or number) assignment can be processed statistically.*

3.40.6 Statistics

Statistics is a type of mathematics. It is a mathematical data analysis system where uncertainty is fundamental, and the results are always expressed in terms of probabilities. Therein, models serve as both inputs and outputs of statistical analyses. Statistical analyses begin and end with models.

Statisticians often refer to the "levels of measurement" of a variable, a measure, or a scale to distinguish between measured variables that have different properties. In statistics, the term measurement is used more broadly and is more appropriately termed 'scales of measurement'. The term 'scales of measurement' refers to ways in which variables/numbers are defined and categorized. Each scale of measurement has certain properties which in turn determines the appropriateness for use of certain statistical analyses.

> **NOTE:** *Drafting scale rulers read architectural and engineering drawings.*

3.41 Level of measurement: Qualitative (categorical)

Qualitative information is determined by the nominal and ordinal level of measurements, which represent techniques (or scales).

3.41.1 Nominal [-level of measurement, scale] - categorized data, name, not numerical

Nominal levels of measurement are used to distinguish between features only on the basis of qualitative information. Nominal data does not imply quantitative differences. The only understanding conveyed is that two things (objects/events) of the same category have a difference (i.e., that in the category containing A and B, that A is different to B. It is meaningless to add, subtract, multiply, or divide nominal data. Attributes are only named; weakest. The assignment of a number. Classification of objects where the fact that the objects are different is preserved. Categorical data and numbers that are simply used as identifiers or names represent a nominal scale of measurement. This is not a 'scale' because it does not scale objects along any dimensions; it simply labels objects. Gender, for example, is a nominal scale: female = 1 & male = 2. The nominal type differentiates between items or subjects based only on their names or (meta-) categories and other qualitative classifications they belong to; thus dichotomous data involves the construction of classifications as well as the classification of items. Discovery of an exception to a classification can be viewed as progress. Numbers may be used to represent the variables but the numbers do not have numerical value or relationship: for example, a Globally unique identifier. Nominal scales were often called qualitative scales, and measurements made on qualitative scales were called qualitative data. However, the rise of qualitative research has made this usage confusing. The numbers in nominal measurement are assigned as labels and have no specific numerical value or meaning. No form of mathematical computation (+,-x etc.) may be performed on nominal measures. The nominal level is the lowest measurement level used from a statistical point of view.

Nominal is without order. Nominal could be considered a qualitative scale technique for grouping into unique categories (e.g., eye color).

Nominal is hardly measurement. It refers to quality more than quantity. A nominal level of measurement is simply a matter of distinguishing by name, e.g., 1 = male, 2 = female. Even though we are using the numbers 1 and 2, they do not denote quantity. The binary category of 0 and 1 used for computers is a nominal level of measurement. They are categories or classifications.

Nominal data refers to data which can be organised into categories e.g. gender: men and women, type of pet: cat, dog, fish, etc. Nominal data does not refer to numbers or quantities. You can't divide a dog by 2 (or at least you shouldn't).

1. A variable that has a nominal-level measurement scale is commonly referred to as a nominal-level variable, or simply, a nominal variable.
2. Define classes or categories, and then place each entity in a particular class or category, based on the value of the attribute.
3. The empirical relation system consists only of different classes; there is no notion of ordering among the classes.
4. Any distinct numbering or symbolic representation of the classes is an acceptable measure, but there is no notion of magnitude associated with the numbers or symbols.

> **TERMINOLOGY:** *Dichotomous – nominal, but two categories only (e.g., male/female).*

3.41.2 Ordinal [-level of measurement, scale] - ordered categorized data, semantic data, name with order, positional, categories with numerical order only

> **NOTE:** *This scale is qualitative, but seemingly quantitative.*

Ordinal scales involve differentiation by class, but they also differentiate within a class of features on the basis of rank according to some qualitative measure. Only rank is involved in ordinal scales. We are able to say that object A has a higher rank than object B, but we cannot say by how much.

Ordinal is nominal with order. Ordinal could be considered is a qualitative scale technique for grouping categories with order (e.g., mild, moderate, or severe; or, 1,2,3). In application, this can sometimes be difficult to separate from nominal.

> **APHORISM:** *Question: What is ordinal? Response: What number are you in line?*

Values assigned to the levels of a variable simply indicate that the levels are in order of magnitude.

Scale for ordering observations from low to high with any ties attributed to lack of measurement sensitivity (e.g., score from a questionnaire).

Ordinal refers to order in measurement. An ordinal scale indicates direction, in addition to providing nominal information. Low/Medium/High; or Faster/Slower are examples of ordinal levels of measurement. Ranking an experience as a "nine" on a scale of 1 to 10 tells us that it was higher than an experience ranked as a "six." Many psychological scales or inventories are at the ordinal level of measurement.

The scale is constructed so that there is an order to all divisions.

> **NOTE:** *Subjective measurement scales may otherwise be known as semantic measurement scales.*

Calculation is possible with ordinal information, through the use of numbers which may be applied to these qualitative scales, which when algebraically calculated, will give a mathematical result (a.k.a., "score").

Ordinal data refers to data which can be put into an order or ranked. Individual items can be organised by importance, general size or some arbitrary preference. Ordinal data ignores the exact degree of difference between individual ranked items. Attributes can be ordered/ranked.

Rank order of that which is being measured. Ordered categories of data. Objects are ranked/ordered based upon a criteria, but no information about the distance between the values is given. An ordinal scale of measurement represents an ordered series of relationships or rank order. The ordinal type allows for rank order (1st, 2nd, 3rd, etc.) by which data can be sorted, but still does not allow for relative degree of difference between them. Examples include, on one hand, dichotomous data with dichotomous (or dichotomized) values such as 'sick' vs. 'healthy' when measuring health, 'guilty' vs. 'not-guilty' when making judgments in courts, 'wrong/false' vs. 'right/true' when measuring truth value, and, on the other hand, non-dichotomous data consisting of a spectrum of values, such as 'completely agree', 'mostly agree', 'mostly disagree', 'completely disagree' when measuring opinion.

1. A variable that has an ordinal-level measurement scale is commonly referred to as an ordinal-level variable, or simply, an ordinal variable.
2. The empirical relation system consists of classes that are ordered with respect to the attribute.
3. Any mapping that preserves the ordering (that is, any monotonic function) is acceptable.
4. The numbers represent ranking only, so addition, subtraction, and other arithmetic operations have no meaning.

Common qualitative, ordinal measurement scales include the following scaling techniques:

1. Likert-type scale (qualitative)

   A. Evaluation-type: little, unsatisfactory, satisfactory, excellent.
   B. Frequency-type: never, rarely, occasionally, most of the tie.
   C. Agreement-type: strongly agree, agree, disagree, strongly disagree.
2. Semantic differential scale – scale includes semantic opposition.
   A. Slow <> Fast; Timely <> Untimely.
3. Summative scale

In this context a scale would give a score (qualitative), a dimension would be an actual measurement (quantitative). For example:

1. Dimension – Length of an object (quantitative).
2. Dimension - Percentage of organisms who die from the same mass dosage of a poison (quantitative; "lethal dose 100/50/30/10).

3.42 Level of measurement: Quantitative (cardinal, metric scale, numerical)

There are three quantitative levels of measurement note here:

1. Interval
2. Ratio
3. Absolute

3.42.1 Interval [-level of measurement, scale] – identified intervals, space between categories is identified

Note: Some statistics software packages may refer to cardinal and ratio data as 'scale'.

Values assigned to the levels of a variable simply indicate that the levels are in order of magnitude in equal intervals. "Interval" itself means "space in between," which is the important thing to remember–interval scales not only tell us about order, but also about the value between each item. Interval scales provide information about order, and also possess equal intervals.

A degree represents the same underlying amount of that which is being measured (e.g., heat if temperature is measured), regardless of where it occurs on the scale.

Interval scales don't have a "true zero." For example, there is no such thing as "no temperature."

Interval scales are those that are known to be linear in some fundamental sense, and are the simplest scale type to allow meaningful comparison of differences. Interval scales typically have an arbitrary zero. Familiar examples include the latitude and longitude scales, which are used to determine position on the surface of the earth. The longitude scale requires two standards to define it: the position of the zero, which is arbitrarily chosen to be Greenwich, and the number of degrees in a full revolution of the earth, which is arbitrarily chosen to be 360. It is possible to compare changes in longitude meaningfully, or to add and subtract intervals of longitude, but it is still not meaningful to talk about ratios. Statements such as 'a country at 40 degrees of longitude is twice the country at 20 degrees of longitude' are nonsense.

Other examples of interval scales include all of the time scales that we use to tell the time of day, date and year, and the 4 mA to 20 mA current loop representation used by many industrial instruments (a symbol need not be a squiggle on paper). One of the earliest thermodynamic temperature scales, the centigrade scale, was an interval scale based on the definition of the melting and boiling points of water at 0 °C and 100 °C respectively. Because interval scales are the first that enable us to talk meaningfully about intervals, these are the first scales that allow us to do normal statistics, that is to calculate means and standard deviations.

Without a true zero, it is impossible to compute ratios.

Interval scales add information about the distance between ranks. To employ an interval scale we must use some kind of standard unit. For example, we differentiate between temperatures by using the standard unit of degrees celsius. We distinguish among elevations by using the arbitrary datum of mean sea level. We cannot multiply or divide interval scale data. For example, it would be incorrect to say 40 °C = 2 * 20 °C. Interval scales have no true or absolute zero. A temperature of 0 °C does not imply an absence of heat, it is just the point at which water freezes.

Cardinal data (also known as interval data) refers to data comprised of consistent units/intervals. Higher numbers mean more of something whereas lower numbers always mean less of something e.g. height, weight, time, temperature, etc. Cardinal data doesn't always have what's known as a 'true zero'.

Distance [between attributes] is meaningful. Differences between values are meaningful. Equal degree/rating (in a 'range') on a scale between two numbers (numerical values). A scale which represents quantity, and has equal units, but for which zero represents an additional point of measurement is an interval scale. The interval type allows for the degree of difference between items, but not the ratio between them. Examples include temperature with the Celsius scale, which has two defined points (the freezing and boiling point of water at specific conditions) and then separated into 100 intervals, date when measured from an arbitrary epoch (such as AD), percentage such as a percentage return on a stock, location in Cartesian coordinates, and direction measured in degrees from true or magnetic north. Ratios are not meaningful since 20 °C cannot be said to be "twice as hot" as 10 °C, nor can multiplication/division be carried out between any two dates directly. However, ratios of differences can be expressed; for example, one difference can be twice another. Interval type variables are sometimes also called "scaled variables", but the formal mathematical term is an affine space (in this case an affine line).

1. A variable that has an interval-level measurement scale is commonly referred to as an interval-level variable, or simply, an interval variable.
2. Interval scale carries information about the size of the intervals that separate the classes.
3. An interval scale preserves order, as with an ordinal scale.
4. An interval scale preserves differences, but not ratios. In other words, the difference between any two of the ordered classes in the range of the mapping is known, but computing the ratio of two classes in the range does not make sense.
5. Addition and subtraction are acceptable on the interval scale, but not multiplication and division.

NOTE: *Occasionally, in common parlance, the ratio scale is considered a second [categorical] class of cardinal measurement, with the first being the interval scale. In other words, there are two sub-categories of cardinal measurement: the interval scale and the ratio scale.*

3.42.2 Ratio [-level of measurement, scale] – measured intervals zero, relation to an absolute datum

Ratio data is the highest measurement scale. All forms of arithmetic operations can be meaningfully applied to ratio scale data. There is a meaningful "zero" value (a fixed origin), and ratios between values are meaningful. Equal degrees on a scale, and the non-existence of a degree is meaningful. The ratio scale of measurement is similar to the interval scale in that it also represents quantity and has equality of units. However, this scale also has an absolute zero (no numbers exist below the zero). Very often, physical measures will represent ratio data (for example, height and weight). If one is measuring the length of a piece of wood in centimeters, there is quantity, equal units, and that measure cannot go below zero centimeters. A negative length is not possible. The ratio type takes its name from the fact that measurement is the estimation of the ratio between a magnitude of a continuous quantity and a unit magnitude of the same kind (Michell, 1997, 1999). A ratio scale possesses a meaningful (unique and non-arbitrary) zero value. Most measurement in the physical sciences and engineering is done on ratio scales. Examples include mass, length, duration, plane angle, energy and electric charge. In contrast to interval scales, ratios are now meaningful because having a non-arbitrary zero point makes it meaningful to say, for example, that one object has "twice the length" of another (= is "twice as long").

In a ratio scale, the following is known:

1. The order
2. The exact value between units
3. An absolute zero
   A. A variable that has a ratio-level measurement scale is commonly referred to as a ratio-level variable, or simply, a ratio variable.
   B. The most common scale in the physical sciences.
   C. It is a measurement mapping that preserves ordering, preserves size of intervals between entities, and preserves ratios between entities.
   D. There is a zero element, representing a total lack of the attribute.
   E. The measurement mapping must start at zero and increase at equal intervals, known as units.
   F. All arithmetic can be meaningfully applied to the classes in the range of the mapping.

A scale in which the values assigned to the levels of a variable indicate both the order of magnitude and equal intervals, but in addition, assume a real zero. The real zero represents the complete absence of the trait that is being measured.

In addition to possessing the qualities of nominal, ordinal, and interval scales, a ratio scale has an absolute zero (a point where none of the quality being measured exists). Using a ratio scale permits comparisons such as being twice as high, or one-half as much. Reaction time (how long it takes to respond to a signal of some sort) uses a ratio scale of measurement -- time. Although an individual's reaction time is always greater than zero, we conceptualize a zero point in time, and can state that a response of 24 milliseconds is twice as fast as a response time of 48 milliseconds.

This type of scale is also known as the metric scale. Metric scales include all of the familiar SI scales of length, mass, thermodynamic temperature, etc. The mass scale is defined in terms of the prototype kilogram stored in a safe in a basement of the Bureau International des Poids et Mesures (BIPM) in Paris. All other measurements reported on the mass scale are expressed as ratios with respect to the kilogram. The standard used to define the scale is known as the metric or the unit of the scale. Metric scales are also known as ratio scales, and the literal translation of the word metrology, from the Greek metrología, is the study of ratios.

NOTE: *The measurement scales for counting oranges and apples are different, because they have different metrics, one orange and one apple respectively, and one cannot take one apple from two oranges and obtain a meaningful result*

The log-ratio scales form a special class of interval scales that are actually based on metric quantities. Because of the very large range of values encountered, it is often convenient to transform metric measurements to a logarithmic scale. These scales are typically constructed as value on log scale = constant × log (value/reference value).

There are two definitions required to define a log-ratio scale: the multiplying constant and the reference value. Examples of such scales include the various decibel scales, the visual magnitude of stars, and the Richter scale for the energy dissipated in earthquakes. On these scales equal intervals correspond to constant multiplying factors of the underlying metric quantity. An interval of 10 dB corresponds to a 10 times increase in power, five steps of visual magnitude correspond to 100 times decrease in the brightness of stars, and two steps on the Richter scale correspond to a 1000 times increase in the energy dissipated in an earthquake.

The progression of scales given above (from lower to higher mathematical operations) suggests that as the nature of quantities and measurements becomes well understood, the associated scales evolve towards metric scales (i.e., a scale with a natural zero).

Some scales can never be metric: colour will always be a three-dimensional scale based on two interval quantities and one metric quantity, and the Rockwell hardness scales will always be ordinal scales.

The counting/natural scale is a metric scale.

With metric scales, an additional possibility is available, namely geometric or harmonic analysis, which is based on distributions measured in terms of ratio rather than interval. An analysis of quantities measured on log-ratio scales using interval statistics is effectively a ratio analysis of the underlying metric quantity.

3.42.3 Absolute [-level of measurement, scale] – measured intervals with true zero, relation to an absolute datum

The ratio scale with an absolute zero (a.k.a., true zero) is sometimes called absolute. No transformation (other than identity) is meaningful. The non-existence of a degree means the non-existence of something in the real world.

An absolute scale is a system of measurement that begins at a minimum, or zero point, and progresses in only one direction. An absolute scale can only be applied to measurements in which a true minimum is known to exist.

Absolute scales are used when precise values are needed in comparison to a natural, unchanging zero point. Measurements of length, area and volume are inherently absolute, although measurements of distance are often based on an arbitrary starting point. Measurements of weight can be absolute, such as atomic weight, but more often they are measurements of the relationship between two masses, while measurements of speed are relative to an arbitrary reference frame.

Defined over a closed set (e.g., objective probability).

1. A variable that has a absolute-level measurement scale is commonly referred to as a absolute-level variable, or simply, a absolute variable.
2. The absolute scale measurement process involves counting the number of elements in an entity set (a conceptualization or pattern). In other words, the absolute scale measurement process involves quantizing the quantity of separations/patterns in a conceptualization or pattern (in a, concept pattern).
3. The measurement for an absolute scale is made by counting the number of elements in the entity set.
4. The attribute (measure) always takes the form:
    A. Number of occurrences of conceptual entity.
    B. Quantity, Unit.
5. There is only one possible measurement mapping.
6. All arithmetic analysis of the resulting count is meaningful.

4 The unit

A measurement necessarily involves a reference frame, and therefore, units. In decades past, there were numerous units, which had little in common with each other. The first coherent system of units only appeared with the French revolution, and it has been given the familiar name, the Metric System.

A unit of measurement (a.k.a., measurement unit, or just, unit) is a real scalar quantity, defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the second quantity to the first one as a number. In physics, a given unit carries the semantic information of a [physical] property [of the universe] and an associated quantity. Hence, a unit is a standard measurement of the same quantity, for the purpose of comparison.

SEDRIS provides useful definitions of terminology herein:

- *Environmental Data Coding Specification (EDCS): 3 Terms, definitions, symbols and abbreviated terms*. SEDRIS Standards. Accessed: January 7, 2020. [standards.sedris.org]
- *Environmental Data Coding Specification (EDCS): 2 Normative references*. SEDRIS Standards. Accessed: January 7, 2020. [standards.sedris.org]

NOTE: *More general, a unit signifies the presence of a quantity or quality.*

The value of a quantity is generally expressed as the product of a [measurement] number and a [measurement] unit. Instances of the same unit category may have a quantitative difference represented by the number. It could be said that a measurement unit is a standardized quantity of a physical property, used as a factor to express occurring quantities of that property. A 'unit of measurement' is a definite magnitude of a quantity (number), defined and applied, that is used as a standard for measurement of the same quantity. Any other value of that quantity can be expressed as a simple multiple of the unit of measurement (e.g., metric is multiples of ten, and time is multiples of 60). In other words, a measurement unit is a standard that is used to measure some physical quantity. A report of a quantitative measurement is not meaningful without its units.

A 'measurement unit' is also known as a:

1. Unit of measurement or units of measure
2. A measurement unit
3. A measurable unit
4. A unit

The measurement of a different sub-category of existence is signified by different units. Therein, units [of measure] are names (not numbers) that signify (characterize) the type of property (concept or system) under measurement, and they associate a standard of comparison to which each is related.

NOTE: *The condition of a system described by its properties (temperature, pressure, etc ...) is defined as its 'state'. At a given 'state', all properties of a system have fixed values. These values may, or may not, fluctuate in time – they may have different values at different states (i.e., dynamic; they may have different values).*

In the language of measurement, quantities are quantifiable aspects of the world, such as time, distance, velocity, mass, temperature, energy, and weight, and units are used to describe their magnitude (or quantity).

A unit must be related to the aspect of the object (system or event) to be measured. For example, a unit of area is required to measure area; area cannot be measured without a linear tool. A linear tool measures length. "We" give a name to a set amount length (i.e., a meter is a meters length). "We" give the name 'meter' to the set quantity length of a 'meter'. Meter and length are both units. The unit name is 'meter', and the dimensional unit [quantity] is 'length'. Once a reference point is established (i.e., a meter is a meter in length), then a scale of units may be created using prefixes, such as kilo (1000, 10-3) and milli (-1000, 10-3). Hence, kilometer is 1000 (or 103) meters, and nanometer is -1000 (or 10-3) meters.

A unit of measurement is relatively arbitrary but consistent. Why is a meter [distance] the quantitative length it is? Why is a second of time the quantitative time it is? These dimensional quantitative amounts have been selected by humans for their ease of perceptual comprehension as quantitative unit reference points from which to base (i.e., compare) existence within a similar conceptual category (Read: dimension).

A measured or counted quantity has a numerical value (e.g., 2.48) representing the quantity, and a unit signifier (whatever there are 2.48 of) representing the constant (fundamental or derived). Hence, when communicating measurements, it is essential to write both the value (#) and the unit (linguistic signifier) of each quantity/constant.

Note that it should not necessarily be presumed that within a single human and/or computational organization where most measurements tend to be reported consistently in the same units, that users will correctly infer the units when they are omitted. The omission of units may lead to unnecessary errors (or, "mistakes"). Further, automatic conversion and computer-assisted calculations become easier with the proper use of unit. It is optimal to always indicate the units.

The first step to check the validity of an equation or an expression in physics is to look at the unit. The units involved in the construction of equations will influence (determine) the form of the equation.

Dimensions and units

In application, the term 'unit' means essentially the same thing as the term 'dimension'. The terms unit and dimension are often used synonymously. However, there are slight differences in definition and rule application in the two alike terms when dimensions are defined as the conceptual quantities of a system, and units represent the name(s) given to a set quantity (quantitative amount) of the dimension. Units and dimensions have the following definitional differences:

1. An equation in which the units balance on both sides of the equal sign is called **coherent**.
2. An equation in which the dimensions balance on both sides of the equal sign is called **homogeneous**.
3. A unit system constructed so that all physical laws are represented by coherent equations is called a **coherent unit system**. Physics, chemistry, and most of engineering are built upon coherent systems.

Units and dimensions have the following rule differences:

1. Dimensions combine by the ordinary rules of algebra. Units do also.
2. Terms which are added or subtracted must have the same dimensions and the same units.
3. Quantities on either side of the equal sign must have the same dimensions and the same units.
4. Powers are dimensionless and unitless (though factors within them may have dimensions and units).
5. Percentages are dimensionless quantities, since they are ratios of two quantities with the same dimensions, and hence, have the same units.
6. dy/dx and ∂y/∂x have the dimensions and the units of y/x (look at the formula for the definition of the derivative).
7. ∫ y dx has the dimensions and the units of yx.
8. Arguments of sin, cos, tan, log, etc., must be dimensionless, but may have units.
9. Sin, cos, tan, log, etc., are dimensionless and unitless.
10. The mathematical constants pi (π) and e are dimensionless and unitless. Specific gravity, being a ratio of two densities, is dimensionless. It has no unit name. Index of refraction, a ratio of two speeds (of light), also has no unit name. Pi (π), the ratio of a circle's circumference to its diameter is therefore dimensionless and has no unit name.
11. Sometimes measurables of physically different quantities have the same dimensions. The commonest example is work and torque: both result from multiplying force by distance. In these cases the unit names are often assigned in a distinctive manner. Names of work units, erg, Newton, etc., are never used for torques.
12. It is also possible for different quantities with different unit names to have the same dimensions. The quantity, 'luminous flux', has the unit 'lumen'. A light's source strength is expressed in the unit 'candela'. A one candela source is said to emit 4π lumens. It may be written, 4πC, where C is the source strength and F is the flux. 4π is dimensionless, so C and F have the same dimensions, even though representing distinctly different quantities with different unit names.

4.1 Measurable, countable, and Non-countable units

Measurable units (as opposed to countable units) are specific values of dimensions [of a system] that have been defined for communication and construction, such as grams for mass, seconds for time, centimeters or feet for length, etc. 'Units of measure' are the unit names given to these concepts (dimensional quantities), including any prefixes and/or suffixes. For instance, the mile and kilometer are both 'units of measure' (recognized as 'unit names') for the 'dimensional quantity' of length. Similarly, pounds, kilograms, and grams are recognized 'units of measure' for mass.

There are also countable and uncountable units (from the two types of nouns in the context of measurement). Countable nouns, otherwise known as unit nouns, have a singular and plural form (e.g., chair, chairs; 1 chair, 2 chairs, 3 chairs, etc. Uncountable nouns are also called mass nouns. Mass nouns only have one form, and hence, are fixed as a singular or plural. Mass nouns are not countable. For instance, it is not possible to say 1 furniture, 2 furnitures, 3 furnitures, etc. Mass nouns cannot be used with an a/an. However, it is possible to use "a part of / an system of" for singular and "some" for plural. For instance, it is possible to say, "a piece of furniture" or "some furniture", and "an item of cloth" or "some cloth".

Non-countable mass nouns (e.g., water and air) can be made into countable nouns by adding units of measure, such as:

1. A glass of water.
2. A liter of air.
3. A cubic meter of land.

Hence, there are:

1. Measurable units (measurable nouns)
2. Countable units (unit nouns)
3. Non-/Un-countable units (mass nouns)
4. Non-countable (mass noun) + unit of measure (known measurable quantity) = Countable units

Whereas,

1. **Unit nouns** usually refer to one or many separate items or units. For instance:
   - A system, systems; a habitat, habitats; an ecology, ecologies; a length, lengths, a width, widths; a mass, masses; a unit, units.
2. **Mass nouns** usually refer to:
   A. Ideas, concepts (e.g. approval, employment)
   B. Substances (e.g. meat, metal)
   C. Liquids (e.g. water, beer)
   D. Powders (e.g. dust, sugar)

There are 4 types of mass nouns:

1. Singular nouns that are always mass nouns (no plural form).
2. Plural nouns that are always mass nouns (no singular form).
3. Nouns that can be unit nouns or mass nouns and have the same meaning.
4. Nouns that can be unit nouns or mass nouns but have different meanings.

In many languages, 'information' is a unit noun, and has both singular and plural forms (information and informations respectively). However, in English and the community in general, 'information' is a singular mass noun; there is only information, and no informations.

4.2 Unit taxonomy

The concept of a 'unit' is taxonomically classified according to the three components of classification, identification, and nomenclature (naming):

4.2.1 Classification

Unit classification includes:

1. **Concept naming** - the logical, orderly naming of units based on derivation location.
   A. **Basic or fundamental units (a.k.a., base units, fundamental units, and dimensional units, fundamental dimensions)** - The smallest set of quantities that are accepted by definition. The basic measurables (a.k.a., fundamental measurable units and dimensions) are the basic/fundamental measurable units or dimensional units of a system. A base unit (also referred to as a fundamental unit) is a unit adopted for measurement of a base quantity (an axiomatic physical, natural property of existence or reality, fundamental dimension). A base quantity is one of a conventionally chosen subset of physical quantities, where no subset quantity can be expressed in terms of the others. The basic measurables of a system are called the "dimensions of the system". Practically, they are the dimensions (parts/coordinates separated axiomatically) of the system. Here, the use of the word, "dimension", is analogous to its use in analytic geometry. In space, any point can be specified by its coordinates measured along axes of a three-dimensional coordinate system (generally signified in a standard manner as: x, y, and z). The dimensions of a quantity do not have an inherent unit association. The dimensions, and hence, units, arise from the logical interrelations between quantities, reflecting the structure of physical laws and definitions.
   B. **Dimensional units** – concepts identifying the base/fundamental dimensions of a system.
   C. **Base/fundamental units (a.k.a, metric units)** – the dimensional quantity associated name. For example, the metre unit as length dimension, kilogram unit as mass dimension, second unit as time dimension, kelvin unit as temperature dimension, etc.
   D. **Multiple units** - express (by name) multiples or fractions of base units, such as minutes, hours, and milliseconds (for time), all of which are defined in terms of the base unit of time, a second. Multiple units are defined for convenience rather than necessity: it is simply more convenient to refer to 3 years than to 94608000 seconds.
   E. **Derived units (sub-units)** - recognized by the dimensions and can be defined as the complete algebraic formula for the derived unit. In a system of measurable units, any derived measurable will be expressed as an algebraic combination of the basic/fundamental measurables (dimensions or basic units) of the system. Derived units are based on base/fundamental units, and can always be represented by these units. In other words, derived units are composed of several other units combined together.
2. **Concept Modifying** - modifying the name of a unit to indicate scale.
   A. **Unit [multiple] prefixes**
   B. A quantity of a unit can be re-written using a different logical name via a prefix multiplication scale. A prefix precedes the associated unit symbol to form a multiple or sub-multiple. This scale re-framing may make reading and calculation of the data more efficient (if human) or less efficient (if computer). For a human, it is easy to multiply by 10, for instance. Metric [unit] prefixes include: deca-, hector-, kilo-, deci-, centi-, milli-, etc. In total, there are twenty

prefixes that have been officially adopted to be used with the Metric Unit System.

4.2.2 Identification

Procedures and methods for determination of an unknown unit.

4.2.3 Nomenclature

The logical naming of all the units in the taxonomy. Note here that there is little logical linguistic naming between the multiple units for the base unit of time, the second and a multiple unit of time, the minute and the hour. What is the relationship between the letters that compose the dimension 'time', the base unit 'second', and the unit multiples minute and hour? The words minute and hour do not appear logically related to 'second' or 'time'.

Summarily, classification refers to the sub-organization of unit-type concepts. Identification ensures that it is possible to procedurally (methodically) determine the unit for a known quantity. And, nomenclature ensures that names are logical, and hence, easy to recall and use.

> **NOTE:** *A 'dimensional analysis' is a scientific analyses conducted to determine the basic/ fundamental measurable (measurable units) of a system.*

4.3 Fundamental and derived units [of measurement]

The basis of the physical sciences is a set of names, definitions, and equations, which allow for awareness, experimentation, and adaptation to a physical environment (i.e., our physical reality).

Not all quantities require a unit of their own. Using physical laws, units of quantities can be expressed as combinations of units of other quantities. Only a small set of units is required from which a more complex functional set can be built. The small set of required units of physical quantity are called base units (a.k.a., fundamental units), and all others units are derived [units]. Derived units are a matter of convenience, as they can always be expressed in terms of basic units.

> **CLARIFICATION:** *A [physical] quantity is a quantifiable [physical] aspect/attribute of the world (the universe, nature, reality), such as time, distance, velocity, mass, temperature, energy, and weight. A 'physical quantity' is a characteristic (property or quality) that can be measured, and which follows the laws of physics (which, describe and/or predict behavior and relationships). Here, physical quantity units are used to describe the magnitude or quantity of a physical aspect/attribute of the world.*

A base quantity is characterized by the following two principles:

1. Base quantities are those quantities which are distinct in nature and cannot be expressed in the form of other quantities.
2. Base quantities are those quantities on the basis of which other quantities can be expressed.

Similarly, a 'fundamental measurement' is characterized by the following two principles:

1. Measurement that is not derived from other measurements.
2. Measurement that is produced by an additive (or equivalent) measurement operation.

Hence, the two types of measurable physical quantities (i.e., physical units of measure) are:

1. **Axiomatic (base/fundamental quantity)**: A quantity that cannot be expressed in terms of other quantities. A quantity that is axiomatic (i.e., fundamental or base), and hence, cannot be defined in terms of the others. Those few which cannot be defined in terms of others, the "basic/fundamental measurable or dimensions", are defined through operational definitions (by specifying a measurement process).
2. **Derived (quantity)**: A quantity that can be expressed in terms of other quantities (/units). This type is not axiomatic, and is defined ("derived") algebraically in terms of other quantities.

In other words, the two physical units of measurement are:

1. **Fundamental units (a.k.a., basic units, fundamental measurable, basic measurable, and dimensions [of a system]** - Those defined by specifying a measurement process (i.e., by operational definitions). A base unit (also referred to as a fundamental unit) is a unit adopted for measurement of a base (fundamental axiomatic) quantity/constant. These are so directly connected with measurement that they are defined by the measurement process. Fundamental units describe axiomatic existent quantities (given what is known) from which all other units can be derived.
   - Base quantities are those quantities that are common to any object.
2. **Derived units (a.k.a., defined measurable)** - Those defined by algebraic mathematical equations in terms of other previously defined and/or fundamental measurables (measurable units).
   - Derived quantities are quantities formed by combining two or more base quantities (using multiplication or division).

Fundamental units may be perceived of from several different problem-oriented contexts:

1. In mechanical problems, a fundamental set of units is mass (M), length (L), time (T). With this fundamental system, velocity V = LT −1 and force F = MLT −2 are derived units. Alternatively, if instead, force (F), length (L), and time (T) are the fundamental system of units, then mass M = F L−1T 2 is a derived unit.
2. In thermodynamic problems (i.e., problems involving heat flow), the concept of temperature (measured, for example, in Kelvin) is a fundamental unit.
3. In problems involving electromagnetism, current is introduced as a fundamental unit (measured, for example, in Amperes in the SI system) or charge (measured, for example, in electrostatic units in the cgs system).
4. In problems involving relativistic mechanics, if mass (M), length (L), and time (T) are fundamental units, then the speed of light c is a dimensional constant (c = 3 × 108 ms−1 in SI-units). Therein, 'c' may be set to equal 1 (c = 1), and mass (M) and time (T) are the fundamental units. This means that length is measured in terms of the travel-time of light (one nanosecond being a convenient choice for everyday lengths).

NOTE: *The 'Rasch Analysis' operationalizes 'fundamental measurement' based on ordered qualitative observations. Therein, 'voltage' as charge pressure, no matter the scale, is the most fundamental measurement for energy.*

4.4 The fundamental, base physical dimensional units [of measurement]

Today, there are seven scientifically recognized basic (base, fundamental) units of measurement, as that which is perceived as a fundamentally constant unit/quantity in the universe. Every other perceived [unitized] measure[able] is derived from those seven.

In other words, in physics, there are seven fundamentally perceivable:

1. Base quantities (detailed in the International System of Quantities, ISQ).
2. Fundamental dimensions of an axiomatic physical existence.
3. Units of [physical] measurement.

In physics, there are seven defined and measurable (dimensional) units. However, all seven fundamental units can be derived with three-four of the fundamental units.

1. Mechanics requires four fundamental measurable unit dimensions:
   A. Kinematical (3 units)
      1. Mass (kilograms)
      2. Length or distance (meters)
      3. 3 length dimension (x,y,z)
      4. Time (seconds)
   B. Electrical (1 unit)
      1. Ampere
2. It could be said that our human experience of the world encompasses five dimensions:
   A. Three linear spatial dimensions (x,y,z).
   B. One mass dimension.
   C. One temporal dimension (time).
3. Electricity requires two fundamental measurable units:
   A. Voltage (eV or Volts, depending on scale)
   B. Time (seconds)

However, it could be said that time is the only true unit of measure; because without time, no change can occur, and thus, no measurement. Measurement involves the perception of a change from a baseline, and change cannot occur without time. Time gives everything its existence, but it is not the true unit of measure. The nature of time is to flow (iterate), and the nature of consciousness is to experience the rate. Time (iteration) is essential in measurement in principle, for instance:

1. A mole is an exact number of "atoms". Measuring a mole requires time.
2. A candela is a measure of "luminocity". Luminocity is dictated by wavelength and frequency. A wave length has no length without time to travel said length, and frequency cannot be determined without measuring this length travelled over a time.
3. A meter is a measure of "length". The very action of measuring length requires time. Can you measure this without time? Grab a 'tape measure' and try. You have already failed as taking the measurement takes time.

That which involves a system in time, involves:

1. **Duration** (of time of system)
2. **Volume** (3x length dimensions of system in time)
3. **Concentration** (mass of system in time)
4. **Intensity** (electric current of system in time)

Take note here that the common properties of physical systems include, but are not limited to:

1. Pressure (P)
2. Temperature (T)
3. Volume (V)

4. Density (D)
5. Mass (M)
6. Energy (E)

It is common in the realm of the elementary particle physics to redefine units so that speed of light and Plank's constant become equal to one, c=1 and h =1. This imposes two constraints on the three kinematical units, and therefore, provides a choice one of the three kinematical units. The units of electrical charge, also, can be, and are redefined (see below). Such system of units is often referred to as Natural Units (natural for the elementary particle physics, that is). The kinematical unit of the choice is energy, E, and it is usually measured in eV (keV, MeV, GeV, TeV). Once c and h are fixed (c=1 and h =1), all other kinematical units can now be expressed in terms of units of energy.

> **INSIGHT:** *If every point in the universe (i.e., every proton has the information of all other protons in the universe) has all the information about the universe (a holographic system), then the universe has the ability to self-organize. Then, every point knows exactly how to self-organize, because all the information is present in every point. We are feeding the universe information, and the universe is feeding us information through all the protons we are made of.*

4.4.1 Geometrized units [of measurement]

A geometrized unit system or geometric unit system is a system of natural units in which the base physical units are chosen so that the speed of light in vacuum, c, and the gravitational constant, G, are set equal to unity.

- c = 1
- G = 1

The geometrized unit system is not a completely defined or unique system: latitude is left to also set other constants to unity. We may, for example, also set Coulomb's constant, ke, and the electric charge, e, to unity.

- ke = 1
- e = 1

The reduced Planck constant, ħ, is not equal to 1 in this system (Stoney units), in contrast to Planck units.

4.5 Physical constant, natural units [of measurement]

In physics, **natural units** are physical units of measurement based only on universal physical constants (a.k.a., the fundamental constants of physics; invariant quantities), and not on human constructs. There are many physical constants in science.

For example,

1. The elementary charge 'e' is given as the natural unit of electric charge, and
2. The speed of light 'c' is given as the natural unit of speed.

A physical constant (a.k.a., fundamental physical constant) is a physical quantity (a.k.a., fundamental physical quantity) that is understood to be both universal in nature and having constant value in time. It is contrasted with a mathematical constant, which has a fixed numerical value, but does not directly involve any physical measurement. Natural units are "natural" because the origin of their definition comes only from properties of nature and not from any human construct (i.e., they can be experimentally demonstrated).

> **NOTE:** *Using dimensional analysis, it is possible to combine dimensional universal physical constants to define a system of units of measurement that has no reference to any human construct.*

Properties of the universe that are likely to have quantity may be represented as natural units. Natural units are intended to simplify particular algebraic expressions appearing in the laws of physics, or to normalize some chosen physical quantities that are properties of universal elementary particles, and are reasonably understood to be constant.

The value of any one of these seven constants is written as the product of a numerical coefficient and a unit, Q = {Q} [Q], where Q denotes the value of the constant and {Q} its numerical value when expressed in the unit [Q]. By fixing the exact numerical value — that is, not assigning any uncertainty to it — the unit becomes defined, as the product of the numerical value and the unit must equal the value of the constant, which is invariant.

There are many natural units (as defined constants), including but not limited to:

1. The speed of light in vacuum - c
2. The Planck constant - h
3. The elementary [electric] charge - e
4. The Boltzmann constant - kB
5. The Avogadro constant - NA
6. The luminous efficacy - Kcd
7. The gravitational constant – G
8. The electron rest mass – me
9. The Josephson constant – KJ
10. The frequency of the ground-state hyperfine splitting of the caesium-133 atom - Δν(133Cs)hfs

A purely natural system of units has all of its units defined by physical constants. Usually, the numerical values of the selected physical constants defined in terms of these units are exactly dimensionless (1).

These constants should not be omitted from mathematical expressions of physical laws; though omission has the apparent advantage of simplicity, it may entail a loss of clarity due to the loss of information, which is otherwise is required for dimensional analysis. Omission of the constant precludes the easy cognitive interpretation of an expression in terms of fundamental physical constants, such e and c.

Throughout all of the formulations of the basic theories of physics, and their application to the real world, there appear certain fundamental invariant quantities. These categorical delineations in our understanding of the reality system of our experiences are called, [fundamental] physical quantities/constants (i.e., fundamental physical quantities and fundamental physical constants). These constants/quantities have specific and universally used symbols.

It is important to understand that most measurements are relative by nature, so only measurements (and units) as the basis for other measurements need to be solitary by nature. Those measurements (or units) that are presently understood to foundation all others are: time, current-voltage, mass, and length. All other measurements (i.e., all other measurables) are based on those units. For instance, velocity is distance per unit of time, Hertz is the number of voltage cycles per unit of time, and calories is the chemical energy (measurable as eV) released per unit mass, etc.

4.6 A unit system (system of units)

A system of measurement is a collection of measurement units, for various concepts of "measure" (i.e., dimensions and units; e.g. length, mass, time), where various units are mutually consistent, and interrelate in a standardized way. Practically, a system of units (a.k.a., unit system) forms a group of pre-determined reference amounts with logical naming. Simply, a standard[ized] set of units is called a 'unit system'. In order to take (i.e., "make") a quantitative measurement, a system of units is required; that is, a set of magnitudes with which to compare those things (properties/attributes) for which comparison (i.e., measurement) is desired.

A system of units is a necessary input for cooperatively measuring ourselves and our environment (Read: the cosmos, the universe, nature, reality).

A set of fundamental/basic units is otherwise known as a 'system of units'. Different fundamental/basic systems of units are based on different choices of base units. A [basic, fundamental] system of units is a set of independent (axiomatic) units from which all other units in the system can be derived. The choice of fundamental units in a particular class of problems is not unique, but, given a fundamental system of units, any other derived unit may be constructed uniquely as a product of powers of the fundamental units.

4.7 Coherent versus incoherent unit systems

A unit system may be either coherent or incoherent. In order to establish a coherent system of units (e.g., the SI) it is necessary to first establish a system of quantities, including a set of equations defining the relations between those quantities. Units therein are consistently constructed and consistently named. Incoherent unit systems have units with no direct relation to each other, and when there are relations, they lack consistency (e.g., the Imperial and US systems). The units within incoherent unit systems are therefore difficult to remember and less efficient to work with.

A coherent unit system is built by choosing appropriately sized basic/fundamental dimensional units for the users' cognition and/or computational parameters. For instance, a meter is given the quantity it has been given, in part, because it is easy for human cognition. The units of other measurable dimensions will then be determined by their defining equations, as combinations of the units of the base/fundamental measurable dimensions, in the same manner as dimensions are determined.

A coherent unit system is a set of coherent axiomatic (base, fundamental) dimensional units that can be used to accurately understand and construct that which is conceptualized. The most widely used system of units is the International System of Units, or SI. There are seven SI base units; all other SI units (non-base) can be derived from these base units.

> **NOTE:** *A logically standardized system of units allows for efficiency in measurement, and hence, efficiency in design, development, and operation [of service systems].*

Take note that in physics, coherent unit systems can presently be built upon a set of basic units that includes only one of the following:

1. When mass is included within the set of basic units, the system is called '**absolute**'.
2. When force is included within the set of basic units, the system is called '**gravitational**'. The fps system is characterized by a gravitational unit of force, called the pound-force (lbf). The unit is so defined that a standard gravitational field exerts a force of one pound on a mass of one avoirdupois pound.

4.8 Common unit systems in use on the planet today

The four most common unit systems in use today are:

1. **The International Metric System (MKS, the [Decimal] Metric System)** is an absolute system. Its basic units are the meter, kilogram, and second. There are several variants of the metric system,

including:

A. **The International System of Units (SI, for System, International**) is the modern/revised form of the metric system, and is the most widely used system of measurement. It has seven basic units, including the meter, kilogram, and second.
B. **The CGS (centimeter-gram-second) system** was once standard in physics.

2. **The FPS (foot-pound-second) system** was once standard in engineering, and is a gravitational system of units.
   - The FPS is an incoherent system.

These three systems (MKS-SI, CGS, and FPS) are all mutually coherent for most branches of physics, especially mechanics (but not including electricity and magnetism). In mechanics, the equations have the same form in all three. In electromagnetics the International System of Units (SI) is used; the FPS system does not account for electromagnetics.

Take note that in the Metric/SI systems, each different kind (dimension) of measurement has a root name, from which other names may be constructed by combining the name with a metric prefix. For instance:

1. Meter, a length unit, forms millimeter, centimeter, and kilometer.
2. Gram, a mass unit, forms milligram, centigram, and kilogram.
3. Liter, a unit of capacity (volume), forms milliliter, centiliter, and kiloliter.

CLARIFICATION: *In mathematics, a 'metric space' is a set for which distances between all members of the set are defined. Those distances, taken together, are called a metric on the set. Therein, a metric space induces topological properties like open and closed sets, which lead to the study of more abstract topological spaces.*

4.9 The International System of Units (SI)

HISTORICAL NOTE: *The metric system of measurement was developed during the French Revolution and was first promoted in the U.S. by Thomas Jefferson. Its use was legalized in the U.S. in 1866. In 1902, proposed congressional legislation requiring the U.S. Government to use the metric system exclusively was defeated by a single vote. As of 2017, outside of the several States (including The United States and Great Britain), there is almost no need to convert metric units into something else, because they use metric units as their physical measurement system. In the United States and Great Britain, multiple measurement systems are used, which introduces the potential for confusion and error, and leads to an inefficient use of time and effort (due to the added necessity to convert).*

The International System of Units is generally seen written as either:

1. International System of Units (SI for Systeme international d'unites), or
2. International System of Quantities (ISQ)

The International System of Units (SI) is the most up-to-date version of the Metric System, and it is formalized as a State agreement that specifies a set of seven base (physical-quantity measurement) units from which all other State agreed upon units of measurement are formed.

The International System of Quantities (ISQ) is a system based on seven base quantities: length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity. Other quantities such as area, pressure, and electrical resistance are derived from these base quantities by clear non-contradictory equations. The ISQ defines the quantities that are measured with the SI units. The ISQ is defined in the international standard ISO/IEC 80000, and was finalised in 2009 with the publication of ISO 80000-1.

The definitions of the terms "quantity", "unit", "dimension" etc., that are used in the SI Brochure are those given in the International vocabulary of metrology, a publication produced by the Joint Committee for Guides in Metrology (JCGM), a working group consisting of eight international standards organisations under the chairmanship of the director of the BIPM. The quantities and equations that define the SI units are now referred to as the International System of Quantities (ISQ), and are set out in the International Standard ISO/IEC 80000 Quantities and Units.

The Metric System (a.k.a., SI) provides a logical and interconnected framework for all physical measurements. The International System of Units (SI) is a modernized, State constructed, version of the Metric System established by international State/corporate agreement.

The SI unit system includes two types of units based on derivation location (axiomatic or sub-derived):

1. SI Base (Fundamental, Metric) Units
   - Currently there are 7.
2. SI Derived Units

The SI includes a coherent set of unit prefix multipliers.

1. Metric prefixes (prefix multipliers)
2. Currently there are +/- 24.
3. What about prefixes for other multiples, such as 104, 105, 10-4, and 10-5? The prefix myria- (my-) was formerly used for 104, but it is now considered obsolete and it is not accepted in the SI. Apparently, no prefixes were ever accepted generally for 105,

10-4, or 10-5, or others.
4. Table: Metric prefixes: Prefix, symbol, meaning, exponential notation.

4.9.1 The 2018 Update to the International System of Units

Updates to 2018 International System of Units

1. Ampere - e is the elementary charge (which defines an ampere). The unit used to measure electrical current. An ampere is the current that, when flowing through two infinitely long, infinitely thin wires that are placed exactly 1 metre apart, would produce a certain amount of force. But infinitely long and thin wires are impossible to produce, so no one can actually test precisely what that value should be. Under the new proposal, an ampere will basically be defined based on the electrical charge of the electron and the proton - something that scientists will actually be able to measure.
   A. The Ampere is the only electrical unit among the seven SI base units. Hence, one might logically expect that all other electrical units, including the volt and the ohm, will be derived from it. But that is not the case. In fact, the only practical way to realize the ampere to a suitable accuracy now is by measuring the nominally "derived" volt and ohm using quantum electrical standards and then calculating the ampere from those values.
   B. In 2018, however, the ampere is slated to be re-defined in terms of a fundamental invariant of nature: the elementary electrical charge (e). Direct ampere metrology will thus become a matter of counting the transit of individual electrons over time.
   C. One promising way to do so is with a nanoscale technique called single-electron transport (SET) pumping. It involves applying a gate voltage that prompts one electron from a source to tunnel across a high-resistance junction barrier and onto an "island" made from a microscopic quantum dot. The presence of this single extra electron on the dot electrically blocks any other electron from tunneling across until a gate voltage induces the first electron to move off the island, through another barrier, and into a drain. When the voltage returns to its initial value, another electron is allowed to tunnel onto the island; repeating this cycle generates a steady, measurable current of single electrons.
   D. There can be multiple islands in a very small space. The distance from source to drain is a few micrometers, and the electron channels are a few tens of nanometers wide and 200 nm to 300 nm long. And the energies involved are so tiny that that device has to be cooled to about 10 millikelvin in order to control and detect them reliably. (Stewart, 2016)
   E. The ampere [A], is the unit of electric current; its magnitude is set by fixing the numerical value of the elementary charge to be equal to exactly 1.602 .10(-19) when it is expressed in the unit [As], which is equal to C. Thus we have the exact relation e = 1.602 .10(-19) [C]. The effect of this definition is that the ampere is the electric current corresponding to the flow of 6.242 10(18) elementary charges per second. The following is not true in SI: The present basic unit of electric current Ampere can't be basic unit because is defined with Coulomb and second. Ampere is not unique unit, because depends on other units. From this is obviously that the Coulomb has no relation whit any other units and because of that it's most convenient this unit to be proposed as basic units.
   F. Previous to 2018: The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2 x 10–7 newton per meter of length.
2. Kelvin - redefined by linking it to the exact value of the Boltzmann constant. Previously, the Kelvin was defined as the triple point of water - the obscure point where water coexists as a liquid, gas, and solid. kB is the Boltzmann constant (which defines a kelvin).
3. Mole - NA is the Avogadro constant (which will define a mole). It was redefined in 2018 by linking it to the exact value of the Avogadro constant.
4. Meter - C is the speed of light (which will define a metre.
5. Second - ΔνCs is the tick of a caesium atom clock (which defines a second).
6. Kilogram - h is the Planck constant (which will define a kilogram). The Planck constant is measured by placing a known mass on one end of a scale, and then, counterbalancing it by sending an electric current through a movable coil of wire suspended in a magnetic field. The electromagnetic force therein is used to measure Planck's constant down to an accuracy of 34 parts per billion.
7. Candela - Kcd is luminous efficacy (which will define a candela).

A dimension is a property that can be measured (e.g., length, time, mass, or temperature) or calculated by multiplying or dividing other dimensions (e.g., length/time = velocity, length3 = volume, or mass/length3 = density).

4.10 Systems of units (in use today)

There are multiple systems of units, some of which are more intuitive and logical (depending on context), than others. There are four categories of unit [measurement] systems:

1. **Traditional unit systems** - Historically many of the systems of measurement which had been in use were to some extent based on the dimensions of the human body. As a result, units of measure could vary not only from location to location, but from person to person. Based on “arbitrary” unit values.
    A. **The Imperial System of Units** used in the United Kingdom and former colonies. It bases its measures on human anatomy (generally, the body parts of royals/imperials) and on common objects that humans use. Early on in human development, people used signifiers like body parts as their units of measurement. For instance, the imperial measurement unit known as a “foot” is about the length of a human foot. An “inch” is about the length of a human thumb. A cup is about the weight of a cup of water. A pound is about the weight of 2 cups of water. Note that there is no common base in the Imperial System. Conversely, in the Metric System, the base unit for all measurements is the number (the de-lineation) 10. The Imperial System includes, but is not limited to the following measurement sub-system units: the Foot, the Pound, the Gallon, and the Mile (statute mile and nautical mile).
    B. **The Market System of Units** used in the State of China.
    C. **The United States Customary Unit System** used in the United States
2. **The [Decimal] Metric Unit System** - A number of metric systems of units have evolved since the adoption of the original metric system in France in 1791. The current international standard metric system is the International System of Units (abbreviated to SI). An important feature of modern systems is standardization. Each unit has a universally recognized size. Both the imperial units and US customary units derive from earlier English units. Imperial units were mostly used in the British Commonwealth and the former British Empire. Based on “arbitrary” unit values, formalized by standards.
    A. **The [Decimal] Metric System of Units** (used for globally-coordinated projects): In the [decimal] metric system, every measure is a factor of 10 units from others. The metric (a.k.a., decimal metric) system uses base 10 for everything, which allows for easy calculation and scaling. It is, in terms of human-mind calculation, easier to work with direct powers of 10 proportions, than any other proportion, and particularly when units are of dissimilar proportion (e.g., inch, foot, yard, pound, ounce, etc.) and dissimilar by geographic location (e.g., UK gallon versus the US gallon). In other words, millimetres, centimetres, and kilometres are interchangeable, whereas feet, yards, and miles are not. When performing a mental calculation, someone doesn’t have to have in mind a table referencing how many inches are in a foot, how many ounces are in a pound.
    B. In distance (reference is ‘meter’): 1M = 100centiM = 1000milliM = 0.001kiloM (or 0,001kiloM).
    C. In volume (reference is ‘litre’ or ‘liter’): 10deciL = 1L = 1000milliL. 10cm x 10cm cube of water weighs about a kilogram, and is otherwise known as a litre.
3. **The Natural Unit Systems** – Unit values that have logically deduced or experimentally demonstrated to occur naturally in science.
    A. **Atomic units (au)** – system of units of measured used in atomic physics.
4. **State/legal Weights and Measures** - To reduce the incidence of retail fraud, many national statutes have standard definitions of weights and measures that may be used (hence “statute measure”), and these are verified by legal State representatives.
    A. **Units of currency** - A unit of measurement that applies to money is called a ‘unit of account’ in economics and ‘unit of measure’ in accounting. This is normally a currency issued by a State, or a faction thereof.

4.11 Systems of units used by Community

A ‘measurement unit system’ is a group of related measurement units.

Currently, there are two active measurement systems:

- Metric (Absolute) Measurement System
    - Contains Metric measurement units: Micrometer, Millimeter, Centimeter, Decimeter, Meter and Kilometer.

- Graphics (Imaging, Visualization) Measurement System
    - Contains GDI measurement units: Pixel, Point, Display, Document, Inch and Millimeter. In graphics measurement units are typically used to express the length, size or location of objects (i.e. some object dimensions).

When multiple unit systems are in common use, it is often necessary to convert the magnitudes of quantities from one system to another. This is accomplished by using conversion factors. Only the defined conversion factors for the base units are required since conversion factors for all other units can be calculated from them. Conversion factors are necessary for interconversion (Read: conversion between systems).

4.11.1 Measurement device units

Currently there are four types of measurement device units:

1. Device - device measurement units are the units of measure of the output device. For instance, with a computer display system, there is only one device measurement unit, and it is called, 'pixel'.
2. Absolute - absolute measurement units are units that do not depend on the device. For example: inches and meters are absolute units, because their length does not depend on the output device (as in, the LCD display, which understands only pixels).
3. Relative - relative measurement units depend on the size of "something else". In a system, relative measurement units are those units that depend on the size of the parent or root objects containing the object.
4. And also, physical and abstract measurement units

4.12 Unit conversion

NOTE: *Units of measurement are not ratios, but ratios are necessary to convert between one unit of measurement and another.*

It is possible to have units that may be converted within and between unit systems. Conversion within a system may be either:

1. *Between unit prefixes* (e.g., between milliseconds and nanoseconds for the dimensional unit 'time')
2. *Between units* (unit quantities) with the same dimension (e.g., between seconds and hours for the dimension 'time')

Conversion between systems is:

- Between units (unit quantities) with the same dimension (e.g., between feet in FPS and meters in IS for the dimension 'length')

Two units (as in, unit names) measuring the same thing, but from different systems, are referred to as equivalents. If a task works in one unit system, but requires input from another unit system, then equivalent units for the specific issue, from the other unit system, must be identified. For instance, if a task uses the imperial unit system, but a specific sub-task requires a metric measurement, then the two systems can be converted between once a metric equivalent (i.e., equivalent metric unit) is identified and its conversion factor is determined.

- **Conversion factors** are homogeneous, but may be incoherent. Their primary use is to transform equations from one coherent unit set to another.

Unit conversion is the process (technique) of exchanging one unit of measure for another unit of measure, while maintaining the associated value (or count).

It is possible to convert within and between unit systems wherever the units mean (measure) the same dimension, object, or event ("thing").

One way to avoid an additional conversion task (and hence, conversion formulas) is to design and apply a single, coherent, and updatable measurement system, such as, the metric system.

Therein, one way to avoid an additional conversion task (and hence, conversion formulas) is to not use unit scale [multiplication] prefixes. However, not doing this can make reading and calculation challenging for humans.

Hence, it is possible (given similar conception) to convert into and out of any other system, and between different levels-of-scales within a single [measurement] system.

4.12.1 Between unit [scale] prefixes

Converting [a quantity] within the metric system [to a different level-of-scale] is known as 'metric conversion' (i.e., intra-metric unit multiplier conversion vs. inter-metric unit multiplier conversion between different measurement systems).

In the metric system, conversion occurs between multiplication prefixes, which include, but are not limited to: kilo, mega, giga, milli, micro, and nano.

Scientific notation is: M x 10n

- M is the coefficient 1<M<10
- 10 is the base
- N is the exponent or power of 10

4.12.2 Unit commensurability and incommensurability

During a task that involves a non-unified unit system, there may be unit types (with unique names) that measure the same thing (same concept), but are based on different [reference] standards. One unit either has a common basis of measured meaning with another (or others), or it does not. If a single unit is present, then commensurability is not an issue.

1. **Commensurable units** have a common basis [for the transfer] of a set value. In order to transfer, a ratio that equals 1 must be present.
2. **Incommensurable units** do not have a common basis [for the transfer] of a set value, and hence, a set value (quantity) of that unit cannot be transferred.

The term 'incommensurable' means 'no common measure', having its origins in Ancient Greek mathematics, where it meant no common measure between magnitudes. In this context, magnitude is just another word for value or quantity. Incommensurable units measure concepts that appear to have no common basis (e.g. meters (length), radians (angle), and kilograms (weight) -- all measure different kinds of things, different concepts.

However, incommensurable [measurement] units can have relationships to each other, for instance, in the way that the weight of a substance might be related to its length, but that relationship may not be a simple ratio, as it is with commensurable units.

Insight: A magnet, for example, is a coherent mass with incommensurability of its atomic structure (its lattice work).

Commensurable means "a common measure". It is of course possible for unit names in different systems [of measurement] to measure the same concept. For instance, "feet" and "meters" both measure [the concept] 'length' (linear movement) in a given direction.

With two commensurable units, one unit can be used to measure the magnitude of another unit (e.g., the meter stick can be used to measure the length of the yardstick, both of which represent some specific magnitude of the same concept, length).

> **NOTE:** *Every conversion represents an inefficiency and the possibility for error.*

Commensurable units, because they measure the same concept, can be converted between. The concept, 'conversion [of units]' is the conversion between different units of measurement for the same quantity, typically through the input of a multiplicative quantity known as a 'conversion factor' or 'multiplication factor'.

There are a number of mathematical ways of actually making the conversions, but the one that is most likely to avoid errors involves making a ratio from the conversion units that equals 1.

The method for converting units comes right from one principle:

- Numbers with units (e.g., 16.2 meters or 32 ft/sec^2) are treated exactly the same as coefficients with variables (e.g., 16.2x or $32y/z^2$).
  - Hence, it is not possible to add 32 ft to 32 ft/sec, any more than it is to add 32x to 32x/y. And, when 32 miles is divided (factored as a ratio) by 4 hours to get 8 miles/hour, which is exactly the same (i.e., conveys the same meaning) as dividing 32x by 4y to get 8x/y.

In mathematics, any number can be multiplied by 1, and its value will not change. <u>Multiplying by 1 - a carefully chosen form of 1 - is the principal input required to convert[ing between] units with a different standards of measure[ment], but measuring the same thing (the same concept)</u>. A fractional (ratio) form of the real number 1 is required.

For example, imagine the requirement of converting a quantity of hours (e.g., 4 of unit 'hour') to minutes (e.g., ? of unit 'minute'). It is given by the metric system that 60 minutes = 1 hour. When both sides are divided by 1 hour. Herein, the unit hour is treated as a variable. As a variable, 60x = 1y, and both sides can be divided by 1y. After the act of dividing creates a ratio. When, for example, (60 min) / (1 hr) = 1, then any measurement can be multiplied by that fraction and its value does not change. If the quantity of the unit 'hour' is 4, then that quantity (4) is multiplied by the specified ratio form of 1:

- 4hr x (60min / 1hr) =
- (4hr x 60min) / 1hr =
- (4 x 60 min) / 1 =
- 240min
- The initial unit quantity is not a dimensionless pure number (4.0), but is a number with dimensions (4 hours). And, the final result is not a dimensionless pure number (240), but is a number with dimension (240min). The dimension (or measurable concept) is the same for both units. A number with units is different from a number without units or with different units, just as 8x is different from both 8 and 8y. If the top and bottom of the fraction are equal, the fraction equals 1, and the value after multiplying is the same as the value before multiplying—but expressed in different units.

The conversion process has three steps:

1. **Identify conversion equation** - Identify (find and/or determine) a conversion factor between the given units and the desired units, which is expressed as a conversion equation.
   - For instance, 1 mi = 1.61 km or 1 km = 0.621 mi.
2. **Identify conversion ratio/fraction** - Determine the fractional form of the real number 1 by converting that equation to a ratio (fraction) with the desired units on top and the given units on the

bottom.

- For instance, 1.61km/1mi [=1] or 1km/0.621mi [=1]. In this case, the multiplication factor for converting from:
- mi to km is 1.6 (1.61km/1mi)
- km to mi is 0.621. (1mi/0.621)
- Note: If the given units are raised to a power, raise the conversion fraction to that same power.

3. **Multiply** – Calculate the multiplication of the original measurement (the measured quantity as 1 unit of) with the multiplication factor (ratio/ fraction), and then, simplify [the units].

In the metric system, the zero point is the same for all units. Some other unit systems set their units zero point to zero too. For instance, 0 pounds equals 0 kilograms, 0 liters equals 0 cubic centimeters, and so on. Take note that between different common unit systems for temperature measurement, is not true: 0 degrees C is a different temperature from 0 degrees F. It is possible to apply the conversion technique to convert between temperature units with different zeros after relating them to a common zero point, and it is more efficient to apply the standard formula as a special case: F = 1.8C + 32. This formula is the slope-intercept form of the equation of a straight line. With other conversions, the intercept is 0 because the conversion line passes through (0,0); but with temperature there's a nonzero intercept because 0 degrees in one measure is not equivalent to 0 degrees in another.

Some conversions are completely impossible, not just impossible using the techniques on this page but impossible by any means at all, because of an axiomatic conceptual contradiction or technical impossibility. For instance, it is not possible to convert 'gallons' to 'square feet' (or liters to square centimeters) using any techniques. This is because gallons and liters measure volume, and square feet or square centimeters measure area. It's like converting x^3 to x^2: it's just not meaningful. A dimensional analysis can be used to show this in a formal way, but informally, remember that area is two dimensions of length and volume is three dimensions of length, and measurements you convert must always have the same number of dimensions.

The following terms mean the same thing: conversion ratio, unit factor, conversion factor, and multiplication factor. This ratio can then be used to multiply the original units to achieve the conversion. Since the ratio = 1 this multiplication does not change the item, it just changes the units.

A conversion ratio (or unit factor) is a ratio [that must be] equal to one. This ratio carries the names of the units to be used in the conversion.

1. **Factor** - It is a determining factor in the conversion.
2. **Ratio** - It is a ratio that carries the names of the units to be used in the conversion.
3. **Unit** - All conversion ratios (unit factors) must equal one.
4. **Multiplication** – The unit quantities are multiplied -- input of a multiplicative quantity. Multiply the measurement (# units you have) by the conversion ratio.

A conversion factor is a ratio (or fraction) that represents the relationship between two different units. A conversion factor or multiplication factor, originally known as 'unity bracket method', is a mathematical tool (a method) for converting between different units of measurement. It is sometimes referred to as a 'unit multiplier'. The method involves a ratio (fraction) in which the denominator is equal to the numerator. The conversion ratio is based upon the concept of 'equivalent values'.

A conversion factor is [a quantity] used to change the units of a measured quantity without changing its value (i.e., its known quantity). Because of the 'identity property' of multiplication, the value of a number will not change as long as it is multiplied by one. Also, if the numerator and denominator of a ratio (fraction) are equal to each other, then the ratio (fraction) is equal to one. So as long as the numerator and denominator of the ratio (fraction) are equivalent, they will not affect the value of the measured quantity.

For example, the unit [of measurement] 'days' may be converted to the unit [of measurement] 'hours', by multiplying the 'days' by the conversion factor 24 (a quantity).

Conversion factor examples include:

- Quantity = [set equal to]= 1 day = 24 hours = 1440 minutes; therefore, 15 minutes (1 day/1440 minutes) = 15/1440 ~= 0.010416667 = ~0.01 days.
- Quantity = [set equal to]= 1 hour = 60 mins = 3600 seconds; therefore, 7200 seconds = 120 mins = 2 hours.

Some unit systems do not have a common basis for their conversion/multiplication factor. In the metric system, however, conversion between units can be discerned by their prefixes (for example, 1 kilogram = 1000 grams, 1 milligram = 0.001 grams). Precision of language is important, and the presence of exceptions (e.g., 1 micron = 10−6 metre) are likely to cause confusion.

4.13 Instrumentation

> **NOTE:** *Measurement instruments are devices that replace the need for actual measuring units (i.e., objects) in making comparisons.*

There are three measurement instrumentation system unit types:

1. **Device** - device measurement units are the units of

measure of the output device.

2. **Absolute** - absolute measurement units are units that do not depend on the device. For example: inches and meters are absolute units, because their length does not depend on the output device.
3. **Relative** - relative measurement units depend on the size of "something else". For instance, a measurement system's units may depend on the size of the parent or root objects containing the measurable object.

5 Numbers

APHORISM: *All is number.*

Number is a syntactic category. A syntactic category is a type of syntactic unit that theories of syntax assume. Word classes, largely corresponding to traditional parts of speech (e.g. noun, verb, preposition, etc.), are syntactic categories. In phrase structure grammars, the phrasal categories (e.g. noun phrase, verb phrase, prepositional phrase, etc.) are also syntactic categories. Dependency grammars, however, do not acknowledge phrasal categories (at least not in the traditional sense).

The word 'number' belongs to a noun of multitude standing either for a single entity or for the individuals making the whole. An amount in general is expressed by a special class of words called identifiers, indefinite and definite and quantifiers, definite and indefinite. The amount may be expressed by: singular form and plural from, ordinal numbers before a count noun singular (first, second, third...), the demonstratives; definite and indefinite numbers and measurements (hundred/hundreds, million/millions), or cardinal numbers before count nouns. The set of language quantifiers covers "a few, a great number, many, several (for count names); a bit of, a little, less, a great deal (amount) of, much (for mass names); all, plenty of, a lot of, enough, more, most, some, any, both, each, either, neither, every, no". For the complex case of unidentified amounts, the parts and examples of a mass are indicated with respect to the following: a measure of a mass (two kilos of rice and twenty bottles of milk or ten pieces of paper); a piece or part of a mass (part, element, atom, item, article, drop); or a shape of a container (a basket, box, case, cup, bottle, vessel, jar).

5.1 Number connections

Notational connections, and the representation of relationships within the concept 'number'.

In mathematics, the concept of 'number' has the following expressed relationships/attributes:

1. **Conception** – natural (counting), whole (direct), integer (inverse), ir/rational, real, imaginary (lateral), complex (angular).
2. **Notation** – the methodological expression of a number.
   A. **Symbol representation** – a sign of operation and/or a representation of a constant [number].
   B. **Numeral representation** – the digits of the numeral system.
   C. **Radix** – the cardinal of the [non-repeated] sequence of digits in the number system.

Every number has the following two attributes:

1. **Value** - The number a numeral represents is called its value.
2. **Sign** - The dimensional direction of the value. In general, there are two signs, positive (+) and negative (-). The number zero (0) has no sign and may be considered to have a neutral sign.

5.2 *Initial mathematical relationships*

When there are two numbers in awareness/memory, the larger will always lie to the right or left (up or down) of the smaller one. Symbols are used to communicate relationships between numbers [on the number line].

The following relationships allow for integrated comparisons between numbers.

There are equality relationships:

- = is equal to, of equal value
- ≠ does not equal, is not of equal value
- ≈ is approximately equal to
- in Mathematica: Set (=) vs Equal (==) vs (identically) SameQ (===).

There are order relationships:

- < less than
- > greater than
- ≤ less than or equal to
- ≥ greater than or equal to

In logic, and hence, mathematics, there is an order to operations (i.e., an order to relationships). In mathematics, this order is known as 'the order of operations'.

The operation minus from the sign of a negative number (as -2 = negative 2).

5.3 *Number*

A number is a count or measurement, that is really an idea in our minds, which may represent a state or condition of the real world.

We write or talk about numbers using numerals such as "4" or "four". We could also hold up 4 fingers, or tap the ground 4 times. These are all different ways of referring to the same number.

> **INSIGHT:** *Number represents movement.*

There are also special numbers (like π (Pi)) that can't be written exactly, but are still numbers because we know the idea behind them.

A number is [the value or count] of a set of something similar. It is the conceptual expression of an iterating pattern. A given pattern may or may not exist, and if it exists, then how many iterations of that pattern exist. Geometrically speaking, it may also be said that a number is the "sum" of identical (indistinguishable) fractal points. The concept "sum" introduces a mathematical concept/unit, sum (or algebraic total of that which is indistinguishable).

As a concept, 'number' represents the presence of the iteration of information (i.e., the presence of patter). Once a pattern is present, logic (as math[ematics]) can be applied to process (calculate). A number is what satisfies the axioms of its number system. In mathematics, a number is a mathematical object used to count, measure, and label.

Numbering and mathematical logic are used to model and understand the universe:

1. To number is to understand iteration.
2. To map is to understand relationship.
3. To calculate is to understand creation.
4. To articulate is to create.

> **INSIGHT:** *The primary function of numbering object and spaces in community is for identification and wayfinding. Numbering allows for coherent creation and dis-creation.*

When a sensation is being measured with numbers, the understanding is language independent, and numeration is language dependent visualized as a specific linguistic expression.

The finite number of digits used in the numbering process is called the **radix/base** [of the selected number system].

Each characterized conceptualization of a number involves the linguistic/logical creation of a 'mathematical construct[ive]' operation (or process). Some of the following characterizations represent groups of constructs. Within that which is termed the "real" number system, there is an increasing order of mathematical constructive complexity, moving from natural numbers at the lowest order, to rational/irrational at the highest order. The misnamed, "imaginary" numbers, represent the extension of the number system into a second, angular (perpendicular) dimension.

Some of the conceptualizations can be viewed as levels or dimensions. For 1 dimension, 1 piece of information is required to define location in that dimension. A real number is sufficient to define location in one dimension. For 2 dimensions, 2 pieces of information are required. Either 2 real numbers or a complex number (note: a complex number holds two pieces of information in a single "number"). If only real numbers are used, then a vector matrix must be generated to hold multiple pieces of information. A vector matrix is not necessary for complex numbers. For both the real vectors and the complex numbers, operations must be defined for translation, rotation, and integration, and duplication (or subtraction). For 3 dimensions, it is possible to use a 1X3 matrix with 3 real numbers in it, or extend the complex numbers to something more complex. The complex number must hold 3 pieces of information, rather than 2. The translation and rotation operations are re-encoded (redefined) to work within each system. To move from 2d to 3d, a new operation is created with another "imaginary" axis. For example of a 2d complex number would be 2+3i. A 3d complex number will be 2+3i+4j. A 4 d number would be 2+3i+4j+5k. The math becomes a lot more complicated ass you add dimensions, and you need computers to do it. Plus humans cannot visualize in more than 3 dimensions. However, the core math stays the same. The imaginary notations are merely notations. Group theory creates different number systems, from natural numbers N, to integers Z, to rationals Q, to reals R, and complex plane C, and on to higher dimensions.

It should be possible to agree on this (*):

- N ⊂ Z ⊂ Q ⊂ R,
  - where, ⊂ means subset
  - When A is a subset of B (A ⊂ B or A subset B), then saying that x is in A implies that it is in B, but not necessarily conversely. Who focuses on A, and forgets about B, may protest against a person who discusses B.
  - When it is said that the rational numbers are "numbers", because they are in R, then group theorists might protest -- the rationals are "only" numbers because: (1) Q is an extension of Z, by including [the mathematical operation of] division; and (2) "we" call them "number" too.
- The elements in R are called numbers.
- The elements in the subsets are called numbers too.

A set (or system) is a collection of objects, typically grouped within braces { }, where each object is called an element (part or sub-system). For example, {red, green, blue} is a set of colors. A subset is a set consisting of elements that belong to a given set. For example, {green, blue} is a subset of the color set above. A set with no elements is called the empty set and has its own special notation, { } or Ø.

5.4 A number system

The real number system represents fully functional field for mapping the real world. A number system is a set of objects (often numbers), operations, and the rules governing those operations.

- A unary [number] system has one numeral in the set {1}.
- A binary [number] system has two numerals in the set {1,2}.
- A trinary [number] system has three numerals in the set {1,2,3}.
- The decimal [number] system has ten numerals in the set {0,1,2,3,4,5,6,7,8,9}.

A number system is the logical composition of sets of symbolic [numeral] digits, that are used to represent the possible enumerations of the concept of 'number'. The system is the concept 'number', which is decomposed into mathematically operative, numerical subsets [of the unified 'number' system set].

The "natural" [counting] numbers form the first set of numbers upon which [mathematical] operations can be performed. This number system begins with the conception of natural counting numbers.

> **AXIOM:** *Counting numbers are the origin of all numbers. Ordered pairs exist – a sequence of patterns exists. ∴ Complex numbers exist. ∴ Complex thoughts exist.*

The concept of 'number' is composed of [at least] the following characterizations, which are otherwise, conceptualizations of the concept, 'number'. Together, the possible numerals at each level of conceptualization are known as a 'set' (mathematical). The sets of numbers in the "real world" number system include, but may not be limited to:

1. **[N] A natural [counting] number (positive integers)** – the concept of, [the numerical mapping of] pattern recognition as a finite sequence of digits, through which an infinite sequence of numbers (numerical meaning) may exist. A finite sequence of digits representing an order of iteration. For example, 1,2,3,4,5,6,7,8,9. There are infinitely many natural numbers; the set of natural numbers is infinite -- as is the set of all squared numbers, the even numbers, the odd numbers, the rational numbers, and the irrational numbers. There is a hierarchy of these infinities, the so-called transfinite numbers. In counting, someone can simply keep adding 1 to the previous number to get more and more. Natural numbers are investigated in an area of mathematics called Number theory.
   - Counting numbers are actual symbols that can be visually expressed and used to represent numbers. Counting numbers are now called positive whole numbers.
   - Number has 'value'.
   - The set of natural numbers.

2. **[W] A whole [counting] number (zero integer)** – the concept of the absence of that which is being counted, together with the principle of a natural number. The absence is commonly expressed with (represented by) the symbol (digit), 0. There is one addition to the finite number of digits in the natural counting conceptualization of 'number',

the absence of the pattern being sequenced. Depending on perspective, zero may be considered unsigned, or may be considered its own sign. Note that the first such “unreal” in the “real” versus “unreal” paradigm was the zero.

- Number has ‘magnitude’.
- The set of whole numbers.

3. **[Z] An integers number (negative integer)** – the concept of a opposite (i.e., different state, direction, or reverse) applied to the sequencing pattern, together with the principles of a natural counting number and a whole number. Sign of a direction - it is common to label certain directions as positive (+, or nothing) or negative (-). Negative numbers are the next most obvious addition, as [in part] the representation of a reverse in direction. If something is not a whole number, then it is not an integer. In other words, an integer can be negative, positive, or zero; and it is at the integer level of the characterized conceptualization of number that the concept of a ‘negative integer’ is added. The conceptualization level is ‘integer’, but the new conceptualization at this level is the ‘negative integer’. A negative integer has a sign in front of the digit, -4,-3,-2,-1. Besides zero (when it is considered a sign), the concept of sign originates from the property of there being a possible “polar” difference in any given number representing the presence of the pattern. The idea of a “change of sign/state” is used throughout mathematics and physics to denote the additive inverse (negation, or multiplication by −1). Note that a decimal number (e.g., 132.493) is not an integer. Integers can be added, subtracted, and multiplied. In application, the negative symbol is just a relative symbol, not an absolute value. In other words, “-5” is not conceived as “negative 5”, but as something opposite of something else.
   - What does it mean to subtract (take away) a larger positive integer from a smaller.
   - Negative integers double the number of elements/digits present.
   - Number has ‘sign’.
   - The set of integer numbers. There are infinitely many integers sequencing in two opposite directions.
   - With the conception of “negative” (inverse) and “positive”(direct), the concept of “opposite” arises (e.g., the opposite of -3 is 3; or, the opposite of unsigned numeral A, is signed numeral A). The “double-negative” property says that the opposite of a negative number is not a negative number (i.e., the opposite of -7 is –(-7).

4. **[R] A real number (a field, plane)** – is a value that represents the quantity [of a sequence] along a single dimension (a line). In between any two given real numbers there exists an infinity of real numbers. Real numbers can be visualized as points on an infinitely long number line. The word “real” was historically introduced to distinguish between the real and imaginary roots of polynomials. The term, ‘polynomial’ comes from poly- ‘many,’ on the pattern of multinomial (a pattern named “term”). A polynomial is an expression of more than two algebraic terms. In other words, a polynomial is an expression consisting of variables (or indeterminates) and coefficients, that involves only the operations of addition, subtraction, multiplication, and non-negative integer exponents. Polynomials are used to form polynomial equations, which encode a wide range of problems.
   - In mathematics, a plane is a flat, two-dimensional surface that extends infinitely far. A plane is the two-dimensional analogue of a point (zero dimensions), a line (one dimension) and three-dimensional space.
   - A field is a two-dimensional plane with the natural addition of vectors.
   - The real number line/set. The mathematical terms line and set, as applied to the real numbers, come from two different philosophical approaches to knowing and naming things. The term line as a representation of the real numbers, such as in the real number line, descended from geometry (Euclid), whereas the use of the term set as a representation of the real numbers, descended from algebra, and specifically set theory, introduced by Cantor.
   - A line has no thickness, because a line is a mathematical construct conceived as a tightly strung string of points (data packets) formed by the junction of two planes, where an infinite subdivision could occur.

5. **[Q] A rational [ratio-nal] number (fractions of prior numbers)** – a ratio (fraction) of any of the individual prior conceptualization, with the exception that 0 is not ever a denominator. Rational numbers are quotients (Q), which are the result of division (i.e., sub-division). In a fraction, the denominator represents the number of equal parts in a whole, and the numerator represents how many parts are signified (i.e., “being considered”). In other words, a ratio of a positive (e.g., using the 1 integer: 1/1, -1/1, 0/1 (is 1), but never 1/0 (which has no meaning and an undefined result). The number above and below are members of

the same integer set. A decimal number (1.5) is a rational number because the digit(s) to the right of the symbol are just another way of writing a ratio (fraction). Rational numbers are integers, and fractions of integers, put together, but there are not any other numbers. All rational numbers may be represented in radix point or fractional form. Fractions/ratios have three forms of notation: radix point notation; fractional/ratio notation; and graph (visual) notation.

A. **Radix point (e.g., decimal) notation** – for example, 0.5. The decimal expansion of rational numbers is either finite (like 0.73), or it eventually consists of repeating blocks of digits (like 0.73454545...).
B. **Fractional/ratio notation** – for example, 1/2 or 1:2.
   1. The expression 1 / 2 represents both the operation of division and the resulting number. This is an example of a “procept“, the combination of process and concept (More completely, a procept is an amalgam of three components: a process which produces a mathematical object and a symbol which is used to represent either process or object.).
   2. The procept property of y/x . In common parlance, there are separate definitional entries for division, quotient, fraction, ration, and proportionality. This is an inconsistent nomenclature. Instead, ratio is the input of division, and number is the result of division. This is not a definition of number but a distinction between input and output of division. It is suggested to use the terms, (static) quotient, for the form with numerator y “divided by” denominator x.
   3. Multiplication is not a precept; there is a clear distinction between the operation 2 • 3, and the resulting number 6. It is also logical to say that 2 • 3 = 3 • 2. The word “multiplication” could be completely replaced by the term ‘group’, and ‘grouping’. With 6 identical elements, there can be organized 3 groups of 2.
   4. (static) quotient[y, x] = y / x
C. **Graphing** – this content is well visualized as a graph. Here, it could be said that there is the notion of proportional space: {denominator x, numerator y}
D. In a two number line graph, the denominator (cause) on the horizontal axis and the numerator (effect) on the vertical axis (instead of reversed), as it should be because of the difference quotient in calculus.

Number as an internally iterating sub-pattern, which may be representable either by a finite number of digits or a [forever] repeating pattern of digits. Number has sub-division.

The language becomes confusing here because, to say, rational seems to indicate that the fractions were somehow qualitatively better, or at least more rational than the irrational numbers

The set of rational numbers -- rationals/fractions are countably infinite. It is often suggested to abolish the word “fraction”. Number means also satisfying a standard form. Thus “number” is not something mysterious but is a form, like the other forms, yet standardised. For example, we have 2 / 4 = 1 / 2, yet 1 / 2 has the standard form of the rationals so that 2 / 4 needs to be simplified by eliminating common prime factors. The standard form (prime factor) of 2/4 is ½. For a standard form for the rationals, the rules are targeted at facilitating the location on the number line, while we distinguish the operation minus from the sign of a negative number (as -2 = negative 2).

If a rational number is equal to an integer, it is written as this integer, and otherwise:

1. The rational number is written as an integer plus or minus a quotient of natural numbers.
2. The integer part is not written when it is 0, unless the quotient part is 0 too (and then the whole is the integer 0).
3. The quotient part has a denominator that isn’t 0 or 1.
4. The quotient part is not written when the numerator is 0 (and then the whole is an integer).
5. The quotient part consists of a quotient (form) with an (absolute) value smaller than 1.
6. The quotient part is simplified by elimination of common primes.
7. When the integer part is 0 then plus is not written and minus is transformed into the negative sign written before the quotient part.
8. When the integer part is nonzero then there is plus or minus for the quotient part in the same direction as the sign of the integer part (reasoning in the same direction).

6. **An irrational [ir-ratio-nal] number (an irrational root)** – a [real] number that cannot be expressed as a fraction. Irrational, but can be expressed on a number line. Some numbers cannot be written as a ratio of two integers; they cannot be expressed as a fraction of integers (non-fractions). It was

discovered that the square root of 2 cannot be written as a fraction. Neither π (pi) nor e can be written as fractions. Note that Cantor, the inventor of set theory, published a paper defining irrational numbers as convergent sequences of rational numbers. What is being observed in the category called the "irrational" (i.e., the irrational numbers) are the numbers that "fill in" all the "gaps" between the rationals [on a number line]. Irrational numbers are those which can't be written as a fraction (which don't have a repeating decimal expansion). Those rational numbers which aren't the result of polynomial equations with rational coefficients.

A. The diagonal of a unit square cannot be represented by a ratio of two integers. And yet, this number does have a direct geometric representation [in the number system].
B. Rationals are the separation of the whole into parts, and irrationals are a unique category of this type of separation.
C. Irrationals are uncountably infinite.
D. The set of irrational numbers.

7. **[C] A complex number (a complex field)** – a field that extends the "real" field, 2D visualization) - A set of real numbers and non-real numbers put together would be a "complex" set of numbers, and hence, the concept given to this category is 'complex'. Complex numbers answer the problem of determining the square root of negative real numbers. Complex numbers are the final step in a sequence of increasingly "unreal" extensions to the [natural] number system that humans have found it necessary to add over the centuries in order to express increasingly sub-divided, significant, numerical concepts. Complex numbers are typically represented graphically as points in the 2D plane, and the rules of addition and multiplication are equivalent to certain operations on lengths and angles. A complex number is a number that has both a Real and an Imaginary part. That is it has 'length' residing along the Real number line (the usual numbers we're all familiar with), what we call the Real axis, and a 'height' residing along an axis perpendicular to that Real number line, which we call the Imaginary axis. In mathematics, the complex plane or z-plane is a geometric representation of the complex numbers established by the "real" axis and the perpendicular "imaginary" axis. This is visualized as a modified Cartesian plane, with the real part of a complex number represented by a displacement along the x-axis, and the imaginary part by a displacement along the y-axis. The concept of the complex plane allows a geometric interpretation of complex numbers. Here, it is the "function" that [visually] distributes the number along the z-axis. Complex numbers form a two-dimensional "vector space" over the "real" numbers. Therein, for each complex number c, there exists real numbers a and b such that c=a + i*b. Here, complex numbers are visualized as a two dimensional plane (the "regular" axis, and the "I" axis). Complex numbers have the added property that rotation in this "plane" is simply a multiplication by a complex number (this, too, has a rigid mathematical definition, that "every R-automorphism is represented by multiplication". Let's call these 3 properties 1,2 and 3.

- Just like coordinates can be plotted on the x,y plane, complex numbers are represented in the complex plane. In a normal x,y plane there is no connection between the two dimensions; there are there are no rules about how they can relate to one another. In a complex plane, there are the rules of algebra. i has to do with rotation on a complex plane. Angles can be determined through the additional use of trigonometry.
- The i as a notation of a complex number, and using notation makes the math more simple.
- It is a field.
- It is two-dimensional vector-space over the reals.
- At every rotation in the vector space is represented by multiplication.
- Every non-contradictory equation, algebraic or transcendental, has a solution within the application of complex numbers. The present understanding is that their addition finalizes (or wholes) the number system into a self-sufficient, consistent system.
- Complex numbers exist in the same way "real" number exists, they're involved in our daily technically computational societal operations. Complex numbers are used for the representation of various physical phenomena, including states of particles and the behavior of electrical currents. They are also necessary (or, at least, efficient) at computing 3D visual space (i.e., computer graphics). All electric and magnetic systems behave like complex numbers express in numerical and graphical notation.
- The Cartesian coordinate system but two such real number lines drawn orthogonally across one another at what is called the origin, used to visualize the mapping of a real function from one real number line called x to another "real number line" called y. The rest of mathematics is supported upon this foundation [of operation].
- Complex numbers are best represented in a

coordinate system were the x-axis shows the real part and the y-axis shows the imaginary part of the complex number. Therein, complex numbers use the Cartesian (x, y; x +iy) coordinates, or use an angle and the distance from a fixed point (the origin) as polar coordinates (rei0).

- The polar equation becomes 1 x e π × i = -1, or e π × i + 1 = 0. This equation is significant because it involves all the fundamental constants in mathematics: 0,1,e,π, and i. These numbers are a numerical-conceptual mapping to relationships in the existent world.
- A complex number is a point on the two dimensional "field" plane of a real number. The absolute value of a complex number is its distance to the origin, and let's call its "angle" the angle it forms with the positive x-axis. The Real numbers are just the x-axis, and "i" is just (0,1). So the real number 1 is (1,0) and -1 is (-1,0). Then multiplying complex numbers multiplies their absolute values and adds the angles. That's why (0,1) times itself is -1 = (-1,0). 90 degrees plus 90 degrees = 180 degrees.

INSIGHT: *In mathematics, the complex numbers are the final step/level/order in the sequenced system of counting numbers [as patterned iterations). From this perspective, every other number is just a sub-set of the complex numbers; the complex numbers are that which is presently understood to be real, and an existent part of the functionally real world.*

8. **A transcendental number** – a transcendental number is a [possibly] complex number that is not an algebraic number—that is, not a root (i.e., solution) of a nonzero polynomial equation with integer coefficients. Hence, a transcendental number is not a finite or repeating set of digits, and also not representable as a root. It is real or complex number that is not algebraic – that is, it is not a root of a non-zero polynomial equation with integer (or, equivalent, ration) coefficients. Transcendental numbers can't be defined as the solution to a specific algebraic equation. Every real transcendental number must also be irrational, since a rational number is, by definition, an algebraic number of degree one.
   - For example, π (pi) - 3.1415926535897...
   - For example, e (Euler's number) is the base of the natural logarithm - the unique number whose natural logarithm is equal to one - 2.71828.
   - Everything that exists follows eternal rules describable as ratios of numbers. Thus, any number could be written as a ratio. For example, 5 as 5/1 or 0.5 as 1/2. Even a number with an infinite decimal sequence can exist as a ratio. All of these are rational numbers. Historically, one number was found to violate this rule. A square with each side measuring 1 unit according to Pythagoras theorem: a2 + b2 = c2. The diagonal of the square length would be square root (sqrt) of 2. Square root of 2 cannot be expressed as a ratio of two integers (e.g., 45/34 or 33/283), and is thus an irrational number because it can't be written as a ratio of two integers.

9. **[i] An imaginary number** - Imaginary numbers are conceived of as numbers, but are not real numbers. Literally, imagined numbers. "Imaginary" numbers visualize a 3d graph. The poorly named "imaginary" numbers (number system) represent the second dimensional (or angular) data point (coordinate) of a number – here, formal relationships can now be constructed (and functions generated) between the two axes (dimensions). All of the [other] "real" numbers are presentable on a one dimensional number line. "Imaginary" numbers exist to extend the functional [mathematical] operation of the numbering system. The poorly named "imaginary" numbers represent an angular separation from the one dimensional number line into a two dimensional numbering system, with the second dimension existing, and capable of being visualized, as perpendicular to the first. Because it couldn't initially be conceived of possibly existing in the real number world it was given the name imaginary or impossible. In response to this understanding, the other set of numbers gets called real. And, when a number contains these two parts, it is called a complex number. Imaginary numbers are not on the "real" number line, but in mathematics, they are just as real as any other formally conceptualized number. Where negatives rotate in 180 degrees , i rotates 90 degrees. i^2 is -1.
   - Imaginary do not exist apart from the real numbers, but exist in what is conceived of as a 90°perpendicular dimension. They are the natural extension of the number system from one to two dimensions. Numbers can be conceived of as two dimensional.
   - The imaginary number [set] – there is only one number here.

Unique conceptual classes of numbers include, but are not limited to:

- Natural number level - Even and odd – every other sequence, with even and odd, existing one sequence off of the other.
- Ratio level - Prime numbers – are numbers whose

factors are 1 and that number. A number that has more than three numbers that go into that number is the opposite. 7 and 3 are prime.

- Natural number level - Infinite numbers – the smallest of which is the number of integers, represented by ℵ0.
- Division-algebra (quaternions octonions)
- Going to 4D (i.e. Quaternion), multiplication is no longer commutative. Going to 8D (i.e., octonions).
- Sign of angle, the "degree" of change between two subdivisions.
- Sign of change - the delta symbol, Δ.

5.5 The zero as unity perspective

> **NOTE:** *The cycling process is called iteration. The output of on operation becomes the input of another, and so on.*

The path the earth follows as it spirals around the sun can be described as 0, a circle, and however, the year is divided, each division is part of the whole 0 cycle. The earth itself rotates around an axis, a circular motion that defines a day as the passage of the risen sun to sunset and back to sunrise.

The number of days can be described as 1 each, or as sets of days, as weeks or months, and in a tangible and quite natural way, the circle, cycle of 0, can be said to be the natural phenomenon that allows each 1 day to exist, just as the earth's cycle around the sun allows a year to exist.

Without the 0 cyclical movement 1 doesn't exist and 1 cycle isn't complete until the circle 0 has been drawn. In both these natural instances, 0 can be said to be a unified 1 or the completion of a cyclical movement that is now designated as 1 symbolic and naturally significant 0. One (1) earth completes each of the circles that describe a visual 0 path, and each 0 has a tangible form that is described by 1 earth and 1 sun. So, does 1 + 1 = 0 or does 0 = 1 + 1.

Does the cycle 0 exist before that which is describing it, or does the cycle 0 only exist because 1 + 1 brings it to the attention of human minds? Zero (0) is a symbol, a tangible cyclical passage that describes unity, but it also describes the completion of 1 day or 1 year.

The end of a year does not result in nothing any more than the end of a day does, they both bring a new cycle, a new 0, that will be unified until the current natural course of events principally determines that the cycle is no longer sustainable, and for the purposes of community, fulfilling. Through subsequent divisions, new 0s, cycles will be formed (as 10,100,1000,10000). In math, these cycles are known as "orders of" [the concept] 'magnitude'. Each cycle is another "level" (a.k.a., "order") of the iteration (as in, a whole new sub-division).

The minds that first described a 0, what we now call zero, didn't imagine it, 0 was real as a unifying circle or cycle, and the concept of someone taking all the candies to leave nothing described something else.

The process of subdividing a fixed line (concept) infinitely leads to something that is infinitely long - the Mandelbrot set. More ("finer") divisions are always possible, and the "finer" the view, the greater the number of divisions. However, mathematically, something which is infinite cannot be measured. Hence, everything which is to be measured must be conceptually and/or mathematically bound.

Non-Euclidean geometry is a consistent system of definitions, assumptions, and proofs that describe objects as points, lines, and planes.

A fractal is something that is self-similar. It is an operation (mathematical process) involving the iteration of an equation with an input coming from an output. Take a number, process it through the 'formula', the result is a number, which is then fed back into the formula. And, that whole process is consecutively iterated, over and over again. What happens when this occurs many times? The structure of numbers that appears is called a 'set' (the Julius set in particular). The Julius set can be visualized (as a whole) on a graph with two axes representing two scales with at least 1 fixed reference point (i.e., with at least one self-similar subdivision). This point represents their unification.

It is possible to understand this, because in mathematics there is a system of definitions, assumptions, and proofs that describe objects as points, lines, and planes (a.k.a., non-Euclidean geometry).

The perspective can be on a one-to-one basis or a one-less-one basis. In concern to a one-less-one basis, the first condition has no condition before it, and hence, zero is conceived. The second one (condition) has one (condition) before it. The third one (condition) has two (conditions) before it. And so on.

The decimal numeral system is a column system until 9 units transcend into zero, a new column. A unifying zero is used because what has gone before is agreed on, and the next column starts with the transcended one, as one ten.

5.6 Continuum

A continuum is a whole of differentiated parts, where the differentiated parts have continuity. The parts are intrinsically differentiated by their relation to the whole, which forms a unified whole. (and hence, the whole is whole/unified). The various analogical uses of the term continuity express the extensiveness of the concept. Relative to the primary analogate, which is the extensive continuum, the parts may be understood under two formalities (eventually becoming formulas, expressions, and arguments):

1. The analytic [part]: a whole that is divisible without end into (analytic) parts, of which there is no smallest. This is interval (the pattern sensation) part.

2. The compositive [part]: a whole, the extremities of whose (compositive) parts are one. This is the sequence part, the iteration. This is a composite of [the following information inquiry processes], which can return data or no data:
    - How many sequential iterations are possible?
    - How many sequential iterations are associated ("take up by") the pattern?
    - Where in the possible sequence of iterating patterns do the intervals start (initiate) and stop (terminate)?

Continuity (without separation, continuous in existence) is logically related to contiguity (bounded in existence, direct contact, complete separation, axiom) and consecutiveness (sequence of separation/occurrence, order); all three (continuity, contiguity, and consecutiveness) refer to extension, but constitute a different ordering of parts. There is the sensation of a whole, and then, its parts and the sequential ordering of those parts.

A whole sub-divides (i.e., "has separation") if some element of a different [extensive] nature integrates ("intervenes") between any part of the ordered whole, to form an interval of parts. Note that it is presently thought that continua (multiple continuous extents, series, or wholes) are encoded into humans cognition means of a scanning motion [of the extensional sensation sub-system].

In other words, a continuum is essentially one, though it has distinguishable parts, whereas both contiguous and consecutive entities are pluralities only, the former with parts distinguished and bounded (separation), the latter with parts separated in sequence (order).

The origin of the notion of continuum is most readily traced to the sensible experience of physical extension, which is the first formal effect of dimensional quantification, manifesting factual material unity but remaining subject to division. "I am that I am" is a definitional phrase for "pattern and sequence", which may be numerically notated as "1,2,3,1,2".

All continua are divisible into parts, that are themselves divisible continua; and since such division does not add anything, the positions of the divisions must be marked by pre-contained indivisibles. Division is generally not considered as a form of separation. The actual division of an abstract continuum is accomplished by the mental removal of a portion of the continuum or the establishment of an indivisible boundary, which becomes a categorically designated separation. Division produces two continua that are either contiguous or consecutive. Boundaries on a continuum of composite parts are resolved by situ or position (the differentia of dimensive quantity). When there are positions (more than one position), then there is geometry in a pattern (or at least, the possible expression of a geometric pattern).

Here, each pattern represents an extensive magnitude, a 'value'. That 'value' position may be fixed as local [motion; i.e., position], or provide relative motion and/or time as a continuum (i.e., relative position).

Though attained in sensation, the abstracted concept of continuum is primarily mathematical; when used in a physical sense, the term is a secondary analogate. It is possible to unity notational priority in the mathematical continuum with experiential priority in the physical continuum. Visually, abstractions are first represented by lines, then angled lines, then surfaces, then three dimensional surfaces, then the iteration of dimensional surfaces (as time).

> **INSIGHT:** *Disagreements about physical existence are often traced to the problem of experiencing reality without an interruption of adaptive continuity.*

There are two types of continuum from the perspective of consciousness:

- In a static continuum, all parts coexist and are known immediately
- In a flowing continuum, the parts, successive in existence, are known only through the re-presentations of memory.

Both types are understood as wholes divisible into parts, distinguished but not interrupted, which have the same nature as the whole; but a flowing continuum is a becoming, hence its parts are never a being, even when considered abstractly.

The mathematical representation of flowing continua requires greater abstraction than that of static continua, since mathematics abstracts from motion. The mathematical notion is subject to further analogical extensions within that order.

Mathematics has one antiquated original separation forming arithmetic (the science of the discrete) and geometry (the science of the continuous). Today, analytical geometry is their unification.

A reference forms a one-to-one corresponding convention to a pattern on an existing continuum. A sensed referential similarity forms a numerical 1 to 1 relationship mapping. From the instantiation of this initial relationship map comes [models and operations for] counting, fractioning, and then, [sub-]dimensioning.

5.6.1 Counting principles

Numerosity is the ability to discriminate arrays of objects on the basis of the quantity of items present. For example, being aware that a quantity of two is different than a quantity of three [of some object/thing].

Five principles defined counting as the process of identifying and operating (functioning) with patterns.

Remember the cooperation from rules theorem:

1. Ideas are [becoming] concepts.

2. Concepts are divided patterns (objects and relationships).
3. Patterns are structured through principles.
4. Principles are "rules".
5. "Rules" are state[ment]s of action.
6. Action is motion.
7. Motion is the result of the instantiation of a resolved information set (space), a decision.
8. An information set (space) resolves into a decision through the logical processing of present information. There may be internal (sub-system, subjective) and external (system, objective) logic here.
9. Logic is pattern recognition.
10. Pattern recognition is awareness.
11. Awareness is the totality of "your" present experience.
12. Counting (sensation) and sequencing (creation) are the basis of technical understanding.
13. Pattern recognition is the basis of intelligence.
14. Logic is the basis of conceptual understanding.
15. Decisioning is the basis of optimization.
16. Motion is the basis of creation.
17. Action is the basis of sensation.
18. Rules are the basis coordination.
19. Principles are the basis of cooperation.

Simplistically, 'abstraction' is the act of giving a short and easy to remember name to something that is long and complicated. By doing this, you absolve yourself of needing to remember the long and complicated stuff. "Abstraction" is the one of the bases of computer science and information processing. In computation, bit patterns represent instructions (operations, processes) for [at least]:

1. Load [an iteration]
2. Store [an iteration]
3. Add [an iteration]
4. Multiply [an iteration]

Bit patterns are hard for humans to remember; hence, they are further encode as assembly language mnemonics (note: assembly language is a base-16, sexadecimal/hexadecimal, number system). Operating systems further abstract the physical hardware that might be connected to a computer, in order to extend functionality (i.e., make it more easily shareable by multiple applications).

For example, in computation, virtual memory is commonly thought of as "paging", which it is, but there is more to the conceptualization. All physical hardware defines a fixed set of categories (names) where program data can be stored. These names/categories are the "physical addresses". If application-programs were forced to always use physical addresses they would constantly have to interrupt/disrupt each other, from which errors are the result.

Virtual memory allows every program to virtually work with some fixed set of addresses, that start at zero, and increase in a finite or infinite . Further, they can pretend that they have this whole address space to themselves. The operating system then takes care of making sure that programs don't end up using the same physical memory or otherwise destroying each other. Again, we simplify high level code by introducing an abstraction layer that essentially does name translation.

The higher-level software applications also have their own collections of abstractions. Some are important enough to have unique names. Most of these applications are constructed out of three axiomatic abstractions:

1. **Model** – how the application stores the basic data (units).
2. **View** – how the application displays the data for the user (entity higher up the supra-systems decision resolution hierarchy). This is the visible part of the user interface (or, the information that is accessible).
3. **Controller** – how the application responds to commands. This is the less visible part of the user interface. It determines which sequences of actions are possible, and thus, what workflows it can support.

In an non-unified model, abstraction boundaries tend to leak out, which is what makes fixing systems in a non-unified model complicated.

An **array** is a systematic arrangement of similar objects – a data structure that contains groups of elements (information sets). When an array is composed of numbers, then those numbers are usually presented in a row and column, matrix, [notational] format. An array is commonly signed with, { } (although there are a variety of other signs).

With the above understandings in mind, the five principles (or principle conceptualizations) of counting are:

1. **The one-to-one principle (a.k.a., one-one principle)** – Assign a single tag (reference association, label, name, category, value, number, word, sign, symbol) to each counted or sequenced object (item, thing, event) in the array [of categorically similar patterns]. In other words, assign only one name/label to each individually counted/sequenced pattern. The two processes required here, to be performed on the collection of objects, are partitioning and tagging. Every item being counted needs to be transferred from the to-be-counted category to the counted category (partitioning), while a distinct tag must be logically associated, not to be used again in

the counting sequence (tagging). If an item is not assigned a number name or is assigned more than one number name, the resulting count will be incorrect (illogical). The two processes requiring coordination:

- The partitioning process (a.k.a., intervaling, pattern recognition) – recognizing [dis]similarity, and the memory/record/awareness its presence. In other words, moving from the to-be-counted category to the counted category.
- The tagging process (a.k.a., naming, label, neologizing) – identifying, selecting, and assigning a tag, name, or otherwise, label/category. Naming the separation of [dis]similarity. There are at least three tags for every [dis]similar pattern:
- A tag representing the category of pattern presenting itself as a sequence/count of intervals and patterns. This is generally notated/expressed as a word (number, e.g., two, three) or letter.
- A tag representing the sequence of the pattern. This is generally notated/expressed as a numeral.
- A tag representing the interval of the pattern. This is generally notated/expressed as a numeral.

2. **The stable-order principle** – The counted tags must be arranged in a stable (i.e., repeated) order. To be able to count also means knowing that the list of words used must be in a repeatable order. This principle calls for the use of a stable list that is at least as long as the number of items to be counted; if you only know the number names up to 'six', then you obviously are not able to count seven items. For example, someone who counts 1, 2, 3 for one particular collection of three objects, and 2, 1, 3 for a different collection, cannot be said to have an understanding of the stable-order principle – although that person would appear to have an understanding of the one-one principle. However, a person who repeatedly counts a three-item collection as 2, 1, 3 does appear to have grasped the stable-order principle – although, in this case, has not yet learned the conventional sequence of number names.
   - From this principle comes the **radix/base** of all number systems.
3. **The Cardinal principle** - On condition that the one-one and stable-order principles have been followed, the number name allocated to the final object in a collection represents the number of items in that collection, its 'value'. The last number-word of an array of counted items has a special meaning: it represents the set as a whole [value] and the numerosity of this set of items. Note that the cardinal principle pre-assumes the one-one and stable-order principles [are encoded]. The final number name is different from the earlier ones in that it not only 'names' the final object, signaling the end of the count, but also tells you how many objects have been counted: it indicates what is called, the numerosity of the collection. If someone recounts a collection ({1,2,3,..}) when asked, how many objects there are, then they have not yet grasped this principle.

These three principles are considered by Gelman and Gallistel to be the 'how-to-count' principles as they specify the way in which the counting operation must be executed (i.e., proceed). The remaining two are 'what-to-count' principles, as they define what can actually be counted.

4. **The abstraction principle** – The real-ization of what is counted. The logical mapping of relationships in consciousness through a nominal "scale" (name only) measure stored in memory.

When the how-to-count principles are combined with the abstraction principle, there is an order of magnitude rise in functional expressibility (i.e., enhanced creativity).

5.7 Numeral

A numeral is any symbol or word for a number. A numeral is a symbol or name that stands for a number. The number is an idea (signified), the numeral is how we write it (signifier). That which is being counted, measured, or otherwise given a numerical value is the sign, or otherwise, sensation.

5.8 Numbers and numerals

A number is a specific value (quantity or [ac]count). Other words for the term 'number' include, but may not be limited to:

1. Quantity – how much?
2. Value – what size?
3. Count – what placement?

There are two types of counts:

1. The points that determine the boundaries
2. The spans between the boundaries.

A 'number' is an abstract [theoretical] concept, and a numeral is the way that people denote that concept. A number is an abstraction represented by a symbol called a numeral. A numeral is a symbol or name that stands for a number. What that symbol looks like is technically irrelevant. However, if a meaningful relationship were present between the symbol and the meaning (number) it conveyed, then that would be optimal for efficient processing. Note that frequently the words "number" and "numeral" are used synonymously/interchangeably, although technically, there is a difference.

Numbers express meaning, and numerals are the symbols (signifiers) used to communicate the meaning. Therein, numbering is the assigning of meaning in the form of a number to something. As an ad-jective, 'numerical' means expressed in numbers, or relating to numbers.

A numeral contains one or more written symbols, but a number can be expressed in a range of ways. A number is a concept whose types can be expressed in [at least] word form (i.e., linguistically; e.g., one, two, three) and symbol form (i.e., mathematically; e.g., 1, 2, 3). The different ways of visually representing numbers are referred to as numerical notational forms.

> **NOTE:** *Something for which mathematical logic has no application is not a number. For example, a so-called "telephone number" is not a number. The symbols/digits in a telephone "number" cannot be added together to get another number, or any relevant mathematical pattern. If mathematics cannot be applied, then symbolized identifier (e.g., "telephone number") is not a number. A telephone "number" is a sequence of digits assigned to a communicating user. It is essentially, the name or address of the user. It is a string of decimal digits (i.e., sequence of digits) that uniquely indicates a network termination point (or user), and is required in the routing of network traffic; it is an identifier assigned to a user. A "telephone number" is a data structure, it is not a single value. Similarly, an IP address is not a number as such, but a string representation of X number of bits/bytes. The IPv4 (protocol) address is made up of 32 bits (4 bytes, 4 octets). The IPv6 (protocol) address is 128 bits (16 bytes, 16 octects). A number is not the same as a location identifier, there is a difference of type.*

5.9 Digits in number system

Digits are the finite number of symbols used in a number system. A digit is a single symbol used to make numerals.

- 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 are the ten digits used in everyday numerals.
- Example: The numeral 153 is made up of 3 digits ("1", "5" and "3").

A digit in base nn is one of the nn symbols used to represent the whole numbers zero through n−1n−1.

For the decimal (base 10) number/numeral system, the digits are: 0,1,2,3,4,5,6,7,8,9 .

Thus, in base ten the digits 0,1,2,3,4,5,6,7,8,9 are used to represent the numbers zero, one, two, three, four, five, six, seven, eight, nine. In base two, binary, the digits are usually 0,10,1 and are used to represent those same ten numbers as 0,1,10,11,100,101,110,111,1000,1001 0,1,10,11,100,101,110,111,1000,1001. In base sixteen, sexadecimal ("hexadecimal"), another six digits are required to represent the numbers ten through fifteen. The digits normally chosen are A,B,C,D,E,FA,B,C,D,E,F.

Digits are used to compose numbers. A digit in mathematics is like a letter in linguistics. A number can be represented by one digit (0-9 are one-digit numbers) or more than one digit (10 and greater are two or more digit numbers). A digit (letter) is one of the individual symbols used in writing a number (word), and the term "numeral" could refer to either one of the symbols or the set of symbols used to represent a number (or concept).

For clarification,

1. Digits make up numerals, and
2. numerals stand for an idea of a number.

A number can be a numeral only, or any combination of numerals and signs. A number can be written with one or more words, letters, numerical digits, or symbols. A number is a concept that has various representations/ notations/expression:

- Twenty one or two ten one
- XLII
- 42
- -42
- 1010102
- 2A16
- 7x6

Something made up of digits is not necessarily a number. A number has a numeral value, while digit is just a representation.

5.10 Unnecessary complexity

More noise is generated by the different "number formats" that have been developed over the course of history. A small sample of the different forms include: 2 + ½ = 2½ = 5 / 2 = 25 / 10 = 2.5 = 2 + 2-1. The deci-mals are a form or result of division.

5.10.1 Numbers as Objective and Subjective

Numbers are an abstraction (conceptual) and do not exist in the real (physical) world. However, just because something conceptualized does not exist in the real physical world, does not mean that it is subjective (i.e., disconnected from the physical world). The number "4", as in, 4 of something (e.g., 4 coconuts), is not something in the real physical world, but it also is not subjective (i.e., disconnected from the physical world). There is an experiential relationship between the numerical signifier "4", the [as]signed numerical meaning "four", and the physical sensation [of 4/four] of something [which can be characterized as unique or different than other things]. The number "4" does not exist, but that does not mean any numerical signifier [of meaning] can be assigned to [the experience and conscious count/awareness of] 4 coconuts. In other words, if 4 coconuts are present in front of someone sensing the real [physical] world, then it cannot be logically said that 3 or 5, or any number/count other than 4 (four), are present.

The scientific method also does not exist in the real world, but that does not mean that the scientific method is subjective. The idea that if something does not exist in the real [physical] world, that it is then subjective[ly disconnected from that world], is not valid. Some conceptual abstractions objectively express an existent relationship in the real physical world, and other conceptual abstracts do not express any relationship to, or in, the real [physical] world.

When there is no experiential reference point for a conceptual abstraction, that conception is commonly said to be "subjective" – related to a separate[d] subject, which is dis-connected from the other (or, all other) subjects in a unified object[ive world].

5.10.2 The real number line: visual positioning

The number line is a series of dots (Read: points, degrees, or packets of information) representing iteration, along a single dimension. Between each dotted sub-division there is an interval. The interval has a beginning, commonly known as it's "position". Therein, the interval's value is the duration of its position. Each interval has a position [of beginning]. That value has a numerical sequence [value] and a unit [value].

> **NOTE:** *Counting necessitates units and sequence.*

A real number line (or simply, number line) allows for the visual display of real numbers by associating them with unique points (positions) on a line. The real number associated with a point is called a coordinate.

Numbers can be conceptualized to exist along a one-dimensional continuum known as a number line (where 0, positive, and negative numbers, fractions, and [ir]rational numbers are all possibly present).

"Imaginary" numbers are not just left or right on this 1st dimensional number line; they exist in a whole different dimension. Algebraically, this new dimension has the expression, the square root of negative 1, √-1. The result of combining a number along the 1st dimensional number line and a number along the 2nd dimensional number line is a functional two-dimensional form, a "complex" number.

The conceptualization of 'number' includes this extra dimension, which has a referential association with the 1st dimensional number line.

Using the word "imaginary" as a label for this category of number conceptualization is a horrible decision. This extra dimension allows for the full visualization of the functional expression: f(x) = x2 + 1. The function crosses the x axis in a two-dimensional graph in this other dimension. This is an extra dimension that the conceptualization of numbers posses. It has been mis-named. The name suggests these numbers are not as "real" as counting numbers, which is not accurate. It has been suggested that these numbers should instead be given the name, lateral. From here on, lateral means imaginary.

The poor selection of a name for the categorically named positioning operation is the most significant reason why people don't understand that a negative times negative is positive, or a pure positive "imaginary" times pure positive "imaginary" is negative real number.

Carl Friedrich Gauss, who gave the first clear exposition of complex numbers and due to his contributions to the theory of electromagnetism, the international unit of magnetic induction is called by his name, the gauss, wrote,

"If we call +1, -1, and √-1 had been called direct, inverse and lateral units, instead of positive, negative, and imaginary (or impossible) units, such an obscurity would have been out of the question." (English translation from German)

Gauss suggested that the concept presently/previously known as "negative" (-) should be renamed as 'inverse' (-). Logically, inverse times inverse is direct. Or, positive is forward, and negative is backward. If the operation is inverse, and then inverse again, of the result is the original direction, like backward and then backward is forward.

The new names [for the positioning operation] are as follows:

- +1 = positive one OR direct one [unit]
- -1 = negative one OR inverse one [unit]
- √-1 = imaginary one or lateral one [unit]

Gauss's "imaginary" number name is lateral number (side number). When direct lateral times direct lateral, which is √-1 * √-1 = -1, then -1 * √-1 is inverse lateral, - √-1, then inverse lateral * direct lateral is direct, -√-1 * √-1 = +1. The square root of a negative number can be solved for with the square root of -1 times the negative number, logically creating the expression of lateral movement (i.e., a movement different to the original axis).

There are two ways to perceive/categorize an angle:

1. Degrees, the swivel an observer went through to follow an object. Degrees are the observers viewpoint.
2. Radians, the distance the object moved on its path. Radians are the mover's viewpoint.
3. 'Radians' are used in operational physics formulas, including but not limited to sine, cosine, etc., wherein 'radians' refers to the distance the object

moved.

5.11 *Mathematical functions*

INSIGHT: *The names applied to concepts and objects determine how easily concepts and objects may be understood, integrated, and visualized. The wrong names are likely to confuse understanding and limit thinking.*

Mathematical operations are also called, functions, expressions, number sets, and operations. Physical operations are also called, formulas, functions, and operations. The mathematical operation is a notation for mapping patterns of [information] movement.

5.11.1 Integral function

Integrals are usually described as the inverse of differentiation, finding the area under the curve, and so on. Integrals allow for the 'multiplication' of changing numbers. Take for example, "3 x 4 = 12"; what if one quantity is changing? It is not possible to multiply changing numbers, so the next operation is to integrate (integration), a more complex multiplication operation.

With regular multiplication, it can be assumed that the value of one unit holds for the entire whole. Integration (piece-by-piece) is required when there is change/time. Time/change becomes a series of instants, each with its own value. Add up the instances (i.e., distance moved) on an instant-by-instant basis.

Multiplication is the combining of quantities into a new result. Changing quantities can also be combined into a new result. The multiplication operation allows for the changing of quantities into a new result, but not directly for changing quantities. Here, integration is the idea of combining quantities into a new result. It is possible to integrate ("multiply") length and width to get area. Area is just one way to visualize multiplication. Yet, it is possible to integrate speed and time to get distance, or length. When integration is required, but the integration operation of multiplication is not possible, then a different integration operation is required.

In mathematics, an integral assigns numbers to functions in a way that can describe displacement, area, volume, and other concepts that arise by combining infinitesimal data. Integration is one of the two main operations of calculus, with its inverse, differentiation, being the other. Given a function f of a real variable x and an interval [a, b] of the real line, the definite integral, $F(x) = \int f(x)\,dx$, is defined informally as the signed area of the region in the xy-plane that is bounded by the graph of f, the x-axis and the vertical lines x = a and x = b. The area above the x-axis adds to the total and that below the x-axis subtracts from the total. The operation of integration is the reverse of differentiation.

In calculus, an integral is written in the following notation and expressing the following relationships. This function[al operation] (a.k.a., integral notation) describes a piece-by-piece multiplication of two elements:

Integral notation (in calculus):

- distance = \int speed(t) \ Δt
  - distance = \int speed(t) \ dt
- distance = ∫ speed(t) \ Δt
  - distance = ∫speed(t) \ dt

The relationships:

- The integral sign (s-shaped curve) means we're multiplying things piece-by-piece and adding them together.
- dt represents the particular "piece" of time we're considering. This is called "delta t" (Δ), and is not "d times t".
- t represents the position of dt
- speed(t) represents the value being multiplied by

Clarifications:

- Writing the operation as "∫ speed(t)", with an implicit dt makes it easy to forget that this is a piece-by-piece multiplication of two elements. Like any function[al operation], when it is described, it should always be described fully.
- Presently, the section concerning speed is written as speed(t) • dt, instead of speed(t_dt) • dt. The latter makes it clear we are calculating for "t" at a particular change "dt", and not some global change "t".
- The way the letters are used is confusing. "dt" looks like "d times t" in contrast with every equation you've seen previously.

NOTE: *Integrals multiply changing quantities.*

5.11.2 Quadratic function

A quadratic function is one of the form f(x) = ax2 + bx + c, where a, b, and c are numbers with a not equal to zero. The graph of a quadratic function is a curve called a parabola. Parabolas may open upward or downward and vary in "width" or "steepness", but they all have the same basic "U" shape.

A quadratic function is graphically represented by a parabola with vertex located at the origin, below the x-axis, or above the x-axis. Therefore, a quadratic function may have one, two, or zero roots. Here, 'roots' are also called x-intercepts or zeros.

5.12 *Integration and the fundamental operations of the concept, 'number'*

The concept, 'number' has the following properties, which represent the fundamental operation[ing] of numbers. A number can have [at least] the following operations repeated on it:

- Counting (sequence[d/ing])
  - E.g., 0,1,2,3,4,5,6,...
- Scaling (order of magnitude)
  - E.g., 1,10,100,1000; 10,20,30,40
- Flipping (inverse)
  - E.g., 1,-1;2,-2;3,-3;4,-4
- Rotating (angle,radian)
  - E.g., 3i;9i;3+4i

The logical conception of a number allows for the technical creation of higher functioning, which requires increasingly "complex" calculation operations.

In part, the purpose of 'number' is to express [the logic of] integration. Multiplication is the understood beginning of [numerical] integration. A number can be broken into units (whole and partial). Then, each unit (piece) can be multiplied (duplicated) by a sequence of iterations, and the results can be added. This is the beginning of [mathematical] logical integration.

The application of integration as "multiplication" results in a unique operation at each consecutive level of conceptualization of the concept, 'number':

1. **The addition operation**: Integers can be added together (integrated) into another number, a piece of data, a result [of calculation].
2. Multiplication operation at integer level of conceptualization: Integers can be repeatedly added together (repeated integration). With integers, multiplication is repeated addition.
3. Multiplication operation at negative number level of conceptualization: with negative numbers, multiplication is flipping.
4. Multiplication operation at "real" number level of conceptualization: with real numbers, multiplication is scaling.
5. Multiplication operation at complex number level of conceptualization: with complex numbers, multiplication is rotating and scaling.

NOTE: *Area is a visual representation (i.e., visualization) of multiplication.*

The conceptual evolution of the addition operation viewed from the perspective of sub-division (or pattern recognition):

1. Addition
   - An additional sub-division/pattern in the sequence
2. Ordered addition
   - Groups of additional sub-divisions/patterns in the sequence.
3. Inverse addition
   - Reverse sub-division/inverse of pattern in the sequence.
4. Repeated addition
   - Multiplication – Effect varies by the level of conception of 'number'.

5.12.1 Division & multiplication

TERMINOLOGY: *Procept – the combination of process and concept.*

Here, one is the variable, a unit [of something].

1. **Sequencing** - Creating another one (sensing another pattern, an equal interval) – the sensation or creation of iteration.
2. **Synthesis** - Combining more than one into one (e.g., 1+1) – integrating two of the same categorical values into one [whole] value of the same category, addition. A "sum" is produced. The operation: addition of two similar data points (values). The result: the sum "product" of those values.
   - Integration -- Repeatedly combining more than one into one (1+1+1) has its own notation, 1x3, multiplication. Multiplication is the repeated integration of a sequence value and a [whole] category value, which produces a new information "product". This number has two data points, sequence [value] and category [value]. Multiplication is repeated addition.
   - The operation:
   - The result:
3. **Analysis** - Separating one into more than one (e.g., 1/2) - subdividing one interval [value] into more than one interval [value]. This is divisioning (as "subtraction").
   - Repeatedly subdividing one or more, into one or more is called "division". Division produces a new information product known as a 'quotient'. Division is repeated subtraction [to form a new interval].

Analysis could be viewed as measurement, and synthesis as the integration of a measurement toward greater understanding and more refined models.

Relationships between division and multiplication operations include:

1. Division is the opposite of multiplication.
2. Division as a process is a multidimensional notion.
3. Division expresses the concept that from a whole [number] there is an equal divisioning [number]. Division is the separation of a number into equal parts. Division may be viewed as a form of repeated subtraction from a whole.
4. Division is the operation of repeated sub-

divisioning. The result of the division operation is new data about a pre-existing number.

5. To divide is to separate one into more than one, equally or unequally. Division is the repetition of separating one into more than one.
6. Multiplication is a form of repeated addition.
7. Multiplication is repeated addition. The result of the multiplication operation is.
8. The multiplication [function as an] operation asks, How many in all; how many [units] in whole [unit]; how many all together?
9. Multiplication is: factor (group sequence) x factor (group value) = product
10. Addition is the combining of two or more. To multiply is to take one out and duplicate it one, and then, combine the sequence and interval values into a "product".

The repeated summation of one "factor" and another "factor". The word factor could be replaced by any word meaning

5.12.1.1 The division model

The division [function as an] operation asks, How many each; how many groups; what is each share/partition?

There are two models for division:

1. Partition division (also known as partitive, sharing and grouping division) is a way of understanding division in which you divide an amount into a given number of groups. If you are thinking about division this way, then 12 ÷ 3 means 12 things divided evenly among 3 groups, and we wish to know how many is in 1 (each) group.
2. Measurement division (also called repeated subtraction division), is a way of understanding division in which you divide an amount into groups of a given size. If you are thinking about division this way, then 12 ÷ 3 means 12 things divided evenly into groups of 3, and we wish to know how many groups we can make.

5.12.1.2 Multiplicative model

Multiplication is:

- To multiply one number *n* (a multiplicand) by another *m* (a multiplier) means to repeat a multiplicand *n* as an addend *m* times. The result of multiplying is called a product.

The multiplicative model is:

- Product (dividend) is factor (divisor) • factor (quotient)
- Dividend – the number being divided
- Divisor or factor – the number that will divide the dividend exactly.
- When a multiplication fact is known, then a division fact must also be known.
- Divisible – can be divided without a remainder.
- Quotient – the result of division

> **CLARIFICATION:** *To duplicate is to make an "exact" (or as close to) copy; a second copy of the pattern. One might offer the idea that instead of subtract, 'sublicate' (reverse of duplicate) means "to take away".*

There are multiplication and division tables. There is one model for multiplication:

1. Repeated addition is the model for multiplication.
2. Multiplier – the number of sets (of a patter).
3. Multiplicand – the value/amount in each set.
4. Product/result – multiplier multiplied by the multiplicand (i.e., multiplier x multiplicand = product). Here, order in the operation is irrelevant.
5. For example, 4x6 = 6+6+6+6 = 24

5.13 Number system and numeral notation

A numeral system or number system is a mathematical system [for the representation] of numbers. A numeral system (or system of numeration) is a writing system for expressing numbers; that is, a mathematical notation for representing numbers of a given set, using digits or other symbols in a consistent manner. It is the applied logic [of a number system] that allows the symbols "11" to be interpreted as the binary symbol for three, the decimal symbol for eleven, or a symbol for other numbers in different bases.

The terms 'number system' and 'numeral system' are often used synonymously. It may be clearer to present a slight differentiation between the two terms, where the term 'number system' represents the internal logic of the system, and the term 'numeral notation' represents the written expression of the system.

> **NOTE:** *The allowance for reusing numerals (symbols) simplifies arithmetic.*

5.13.1 Radix/base

Every number system has a specific [finite] number of unique digits known as its base/radix (i.e., the number of unique digits in the system).

In mathematical numeral systems, the radix or base is the number of unique digits, including zero. Etymologically, 'radix' is a Latin word for "root". Root can be considered a synonym for base in the arithmetical sense. For example, for the deci-mal system (the most common system in use today, coming from the ten fingers/digits of humans) the radix (base) is ten, because it uses the ten digits from 0 through 9. If numerical representations greater than 9 are required, then a new position is required (10,11,12,13,14,...,99,100,...,999,1000...).

> **DEFINITION:** *The word "base" in mathematics is used to refer to a particular mathematical object that is used as a building block.*

5.13.2 Positionality

Number/numeral systems may be categorized by either positional or non-positional notational encoding logic. There are two primary ways in which numbers can be represented/encoded. They can either be encoded positionally, or encoded without position having meaning (i.e., non-positionally). Positional [numeral system] notation is distinguished from non-positional notation by its use of the same symbol for different "orders of" magnitude (different meanings). For example, the "ones place" (1), "tens place" (10), "hundreds place" (100) – the 1 repeats three time, and means something different each time (one, ten, then hundred). In a positional numeral system, the position of any given digit in a number has [logarithmic] mathematical significance.

5.13.3 Non-positional

Non-positional number/numeral system (non-positional notation) – Characters/digits are position invariant, meaning each character represents the same value regardless of its position. In Roman numerals, for example, the symbol V always means "five", whether it occurs last in a numeral string (e.g., XXV), next to last (XXVI), third from last (XXVII) or fourth from last (XXVIII). In the Roman numeric system, each numeral has a fixed value, rather than representing multiples of the base number (e.g., 10, 100, and so on), according to position. Hence, there is no need for "place keeping" zeros. Notice that in the Roman system, position still has relevancy (e.g., I before V or X indicates one less), but that relevancy has no fixed zero relationship, no positional relevance [relative to the number as a whole].

The unary (base-1, tally marks) numeral system, frequently used for counting, is non-position: /=1; //=2; ///=3; ////=4; /////=5; //////=6; etc.

> **NOTE:** *Arithmetic operations are possible, but more difficult.*

Non-positional number systems have a base number of repeating digits, which may be 1 or more. However, they are not (generally) categorically named after their base, they are given cultural names.

Note: It could be said that there are cultural number/numeral systems. Cultural numeral systems involve unique character/symbol visualizations, and they include but are not limited to: Babylonian, Egyptian, Vedic, Greek, Roman, Chinese, Arabic, Hebrew, Indian, etc. In this category, the numerals and their rules are viewed as having arrived due to unique cultural values and symbols. Simply, a cultural numeral system is the name of any given numeral system a specific "culture" uses, and it may be positional or non-positional.

5.13.4 Positional

Positional number/numeral system (positional notation, place-value notation) - Place (position) has value (meaning). Where a digit occurs in a number (as a string of digits) determines its meaning. A positional number system gives different meaning to the same symbol depending on its position. The position dictates rules to manipulate the symbols, not their value (magnitude). In a positional number system, the value of each digit is determined by which place it appears in the full number. A positional (numeral) system is a system for representation of numbers by an ordered set of numerals symbols (called digits) in which the value of a numeral symbol depends on its position. For each position a unique symbol or a limited set of symbols is used.

The base of a positional number system is, how many digits (symbols) there are for each position in a number.

In a positional system, the value of a symbol is given by the order of its position expressed in the bases (or radices) of the system. The total value of the represented number in a positional number is the sum of the values assigned to the symbols of all positions. For each position that the number is in, in that system has a relative symbol or meaning, and in a way relates to the number directly next to it. The total value of a positional number is the total of the resultant values of all positions. For each position that the number is in, in that system has a relative symbol or meaning, and in a way relates to the number directly next to it.

In a positional [notation] numeral system each position is related to the next by a constant multiplier (i.e., base) of that numeral system. The different numeral systems sub-categorized by different bases are given the suffixes -ary, -imal, and -al. Each position represents a different base.

Positional number systems are categorized by their radix/base. Each iteration of the base forms a magnitude of sequentially iterating order (known as "orders of magnitude").

There are generally considered two sets of rules for encoding positional information: [a] "standard" [set of] rules; and [a] "non-standard" [set of] rules:

1. Standard positional numeral systems/notation – whole number orders of magnitude from base/radix 2 onward.
    A. Binary, ternary, quaternary, quinary,...,decimal, sexagesimal,...
    B. The non-standard positional numeral systems are.
2. Bijective numeration
    A. Signed-digit representation

B. Negative bases
C. Complex bases
D. Non-integer bases

In any standard positional numeral system, the number x and its base y are conventionally written as (x) y, although for base ten the subscript is usually assumed and not written, as it is the most common way to express value (by our organism, because of our 10 fingers). For example, (100)10 (in the decimal system) represents the number one hundred, while (100)2 (in the binary system with base 2) represents the number four.

The radix point

With the use of a radix point ("."; e.g., decimal point in base-10), the positional notation can be extended to include fractions and the numeric expansions of numbers into rational and real categories (i.e., into a "real" [one dimensional, root = base/radix] set). Note that the point/dot takes on the name of the numeral system. For example, the point/dot in the:

1. Binary numeral system may be called, a binary point.
2. Quinary system it may be called, a quinary point.
3. Decimal system, it may be called, a decimal point.

5.13.5 Scale

NOTE: *In order to communicate results unambiguously it is necessary for each of us to share the same scale for a quantity and to have access to the standards that define the scale.*

A scale is a totally ordered numerical structure onto which physical quantities are mapped, with the mapping preserving the structure of the original physical quantity. Every scale can be realized using mathematical concepts.

Length and angle scales are realized with mathematical concepts. Hardness, temperature, and other environmental scales are realized using concepts from physics rather than mathematics. Both length and angle scales are linear scales. Length requires a unit length to be defined. Early unit length standards were realized as end bars,in which the fundamental unit was the distance between the two ends of the bar. The meter, the fundamental unit of length, is now defined from concepts in physics, rather than being based on the results of a mathematical survey of a geographical artefact.

The fundamental unit is then divided upon a continuum, into a 'scale'. It may be divided equally, or unequally (and its visual representation as equal or unequal depends upon the particular notation). Mathematically, division is interpolation, which is the computation of new data points from known discrete points. For the length scale, this consists of dividing the unit length, defined by a line scale, into equal lengths, and for angular scales, dividing the circle into equal angles.

Euclid's Elements provides various geometrical constructions to divide lengths into equal parts and constructions for particular angles and angular bisection.

NOTE: *A 'chart' is a two-axis scale (or continuum). A three-dimensional 'Cartesian coordinate system/scale' is a three-axis scale (e.g., x,y,z).*

A scale is a system[s approach] that we use to perceive [existence], by the method of arranging data [of a similar pattern] in [logical] order.

Every scale requires the following elements:

1. Visually expressed with iterative markings representing the division of a pattern.
2. An ordered numerical/linguistic notation.
3. At least one categorical dimension.

The word scale has several applications, all of which relate to the idea that there exists a divisional iteration of a pattern.

CLARIFICATION: *The term 'continuum' has a relationship to the concept of 'scale'. A continuum is a set of iterations on a scale, which have a particular characteristic to different degrees. Any continuous whole comprising of individual units with a logical progression can be considered a continuum. The term is also given to a body that can be continually sub-divided into infinitesimal elements with properties being those of the bulk material. And, a continuum is a region of filled space.*

5.13.5.1 A 'scale' as a tool for understanding a discontinuous category - scale as a discontinuous category (understanding)

There exists a pattern, and the pattern repeats along an ascending or descending scale. Here, a scale is a conceptual-mathematical visualizing tool for divisional categorization. Numbers can be placed/positioned in order (as intervals) along one or more lines to create a visual scale, which represents a discontinuous category of information. The numerical space between divisions may be equal or unequal.

A number/numerical scale is a line on which the marks of separation have been given numerical names or labels. A number scale is constructed by starting with a line, and a line segment of fixed amount (or magnitude), which represents the first level (or order) of magnitude. Levels (or orders) therefrom may exist at equal or unequal separated magnitudes.

A 'scale' is a way of visualizing spatial size/quantity categorizations with division marks indicating (divisioning, sectioning, or proportioning). Here, a scale is a type of discontinuous, ordered rank of categories or sizes. More generally, a 'scale' refers to a differentiated category of size. Here, the term 'scale' implies the discontinuous (divisioning) idea of, orders of magnitude.

A scale forms a sequence of ascending or descending units/intervals of equal or unequal proportion.

> **NOTE:** *A scale can be used as an organizing structure for understanding something.*

A scale mathematically and/or visually represents portions of a whole. A proportion is a way of expressing how the size or magnitude of one thing relates to that of another.

The degree of separation between iterations (e.g., adaptive repetition of 0-9 (1st order of magnitude), to 10-99 (2nd order of magnitude), and so on) may be conceived of as a number, named a 'radix' or 'base'. There are ten [conceptual] degrees of separation between each iteration in the deci-mal number/numeral system (0-9). When these iterations are expressly notated along a [number] line, that is called a number scale.

Each iteration [of the pattern] on the scale (1,10,100,...) represents a positionally relevant ["order of"] magnitude based on the base/radix of the applied number/numeral system. The presence of an ordered difference (rank) among a set of something similar is embodied by the word "order", as in, "order of magnitude".

The order of magnitude [of a scale] is dependent on its base (radix), and on whether the scale is linear or non-linear.

A scale may have equal or unequal divisioning. A non-linear scale consists of unequally spaced divisions (sections or proportions). A scale that has equal divisions is called 'linear', and an unequally divided scale is called 'non-linear':

1. **Linear scale (equally divisioned scale, proportional scale)** – where the divisions (marks) are evenly spaced. On a linear scale, a change between two values is perceived on the basis of the difference between the values. For example, a change from 1 to 2 would be perceived as the same amount of increase as from 4 to 5. Visually, each line, grid or marking [visible on the scale] is equal in value or size. The divisions, sections or proportions on a linear scale are directly proportional (i.e., equal). The relationship between the variables is directly proportional. Thus, a linear scale is sometimes called a, **proportional scale**. A proportional/linear scale always has an "order of magnitude" [off difference between intervals] of one.
   A. As a "gauging/comparing" tool, the linear scale is used to obtain the accurate measurement of: distance, mass, volume, etc.
   B. Machines utilize a linear scale in order to produce precisely desired outputs. Examples of linear scale tools include: ruler, measuring tape, measuring cylinder, graph sheet, etc.
2. **Non-linear scale (unequally divisioned scale, non-proportional scale)** – where the divisions (marks) are unevenly (or not equally) spaced. The relationship between the variables is not directly proportional. In a non-linear scale, the divisions, sections, or proportions are uneven/ unequal. This means that the visible lines, grids, or other divisional markings (which may appear equally spaced in the visualization) are not equal or constant in value or size. The divisions, sections, or proportions are not directly proportional. Thus, a non-linear scale is sometimes called a, **non-proportional scale**. Note that because the divisions (marks) are not evenly/equally spaced, it is more challenging for a human to accurately read the scale.
   A. The **logarithmic scale (order of magnitude scale)** is a well-known type of non-linear scale. Visually, each mark on the log scale is the previous mark multiplied by a value. In a logarithmic scale, values are proportional to the logarithms of the scale numbers. On a logarithmic scale, a change between two values is perceived on the basis of the ratio of the two values. That is, a change from 1 to 2 (ratio of 1:2) would be perceived as the same amount of increase as a change from 4 to 8 (also a ratio of 1:2). A logarithmic scale implies and is based on "orders of" magnitude, rather than individual incrementation, as in a linear scale. Each mark on the logarithmic scale is calculated to be the previous mark multiplied by a value set for the log. A logarithmic scale is marked off in orders of magnitude, that is, each mark on the scale as you move left to right is larger by a multiple of the scales set value, than the one preceding it. If the scales value is 10, then one mark to the right is 10 times larger and one mark to the left is 10 times smaller. On a linear scale the distance from 1.00 to 10.0 is ten times longer than the distance from 0.1 to 1.0. On the logarithmic scale these two distances are equal. Take note that logarithmic does not always mean base 10.
   B. The decade log scale is one of the most well-known log scales. One decade is a factor of 10 difference between two numbers (an order of magnitude difference) measured on a logarithmic scale. A decade is a set of ten, or an interval of ten. In the decade log scale, there is a base 10 interval between increasingly higher order whole-number exponentials. For example, 100(1), 101(10), 102(100), 103(1000, 1k), 104(10000, 10k), 105(100000, 100k).
   C. One of the most well-known ratios is the "golden" ratio (phi). In geometry, a golden

spiral is a logarithmic spiral whose growth factor is φ, the golden ratio. The Golden ratio is a special number found by dividing a line into two parts so that the longer part divided by the smaller part is also equal to the whole length divided by the longer part. It is often symbolized using phi, after the 21st letter of the Greek alphabet. The term 'Phi' was given to the ratio number "in honor of Phidias, the lead sculptor of the Parthenon in Greece". In an equation form, it looks like this: a/b = (a+b)/a = 1.6180339887498948420 ...

CLARIFICATION: *In a non-linear system a change in the output is not proportional to a change in the input. In a linear system, a change in the output is proportional to a change in the input.*

5.13.5.2 A 'scale' as a tool for comparing (gauging)

A scale is a tool used to compare new information to a pre-existing [dimensional] iterative pattern of information, producing new data. A "scale" often signifies a receptor or method that can reliably map a number to a given phenomenon. In this usage, the term may also be part of the proper name of the method signified. This usage implies a comparison of entities, but not the discontinuous idea of "orders of magnitude".

As conceptual instruments, for example: the Mohs scale (hardness), Scoville scale (heat of capsaicin), Kelvin scale (temperature), ph scale, Borg scale (physical exertion), Richter scale (earthquake), and stellar magnitude.

As a physical tool (instrument), confusingly, a scale is also the name of a measuring instrument for weight, as well as another name for a ruler (an instrument for measuring length). Common [physical] length scale measurement gauges include: the Vernier scale, linear scale, engineer's scale, architects scale, scale of duration, scale of calibrated dial.

CLARIFICATION: *Measurement display "gauges" are instruments most often used in situations where the thing being measured changes regularly in time, such as in the measuring of volume of something we being used (e.g., fuel gauge).*

5.13.5.3 Scale in mathematics (fractioning)

"Scale" is a common term in mathematics, usually signifying a proportion. This usage implies a comparison of entities, but not the discontinuous idea of "orders of magnitude".

5.13.5.4 Scale as continuous representation system (modeling)

"Scale" can refer to a continuous representation system (model) that signifies an inter-related set of phenomena. This usage implies a comparison of entities, but not the discontinuous idea of "orders of magnitude". One thing represents another thing, but at a different size. The 'scale ratio' of a model represents the proportional ratio of a linear dimension of the model to the same feature of the original.

For example, a smaller 3-dimensional "scale" model of a building, or the scale[d down] drawings of the elevations or plans of a building.

The scale can be expressed in four ways: in words (a lexical scale), as a ratio, as a fraction and as a graphical (bar) scale.

- Lexically - One centimeter to one meter
- Ratio – 1:100
- Fraction – 1/100

To scale something is to produce a smaller or larger representation of something. The scaled [down] version of the thing is somewhat confusingly called a 'model' [representation]. A "scale model" is a [physical] model, a representation or copy of an object that is larger or smaller than the actual size of the object, which seeks to maintain the relative proportions (the scale factor) of the physical size of the original object. Very often the scale model is smaller than the original and used as a guide to making the object in full size.

Other examples of a scaled representation system include: the scale on a topological map, a musical scale, and a gauge of measurement.

An object (or representation) can be scaled proportionally and non-proportionally.

1. If an object is being scaled, and its representation maintains proportions after scaling, then it is a proportional scale (i.e., the scaling process/ operation used a fixed ratio).
2. If an object is being scaled, and its representation does not maintain proportions, then it is a non-proportional scale (e.g., it may have been scaled along the x-axis, and not equally along the y-axis). This type of scaling is sometimes known as sub-dimensional scaling (i.e., scaling of the unique dimensions of some thing).

5.13.5.5 Scale as providing numerical measurement

Scaling is a term used to describe the way that an operational definition can be conceptualized to provide numerical measurement. Usually the term is applied only to ordinal or interval level measures, as nominal scaling is really just a matter of classification within a set of categories, as we saw above. There are a vast number of different scaling techniques and procedures.

1. **Counting frequencies** - the simplest scaling involves natural measures like the counting of instances of occurrence of events. Such occurrence

is absolute in nature and can be measured in terms of its “frequency”. Scales reflecting measures of frequency are at the ratio level of measurement.

2. **Measuring magnitude** - of which the Likert scale is a typical example. In this measurement procedure, verbal “anchors”, which define the extremes of the dimension being measured, are provided to allow a range of responses to some specific question. It is a mistake to assume that the measurement obtained from magnitude scales such as the ones above is at the interval or ratio level because we have no way of determining that the distances between adjacent scale points are really equal.

5.13.6 Order of magnitude

The term/phrase ‘order of magnitude’ is used to mean more than one thing. The term ‘order of magnitude’ has two meanings. In its first meaning, it refers to a type of scale. In its second meaning, it refers to a degree (or iterative mark) in a scale of the ‘order of magnitude’ class. Here, orders of magnitude also known as degrees of separation, and an ‘order of magnitude’ is one degree of separation, one interval (one sequence).

5.13.6.1 In concern to the term as a class of scale

An order of magnitude is the class of scale (or magnitude) of any amount, where each class contains values of a fixed ratio to the class preceding it. In other words, an order of magnitude is a scale of repeating numerals with a fixed multiple factor (ratio). Here, the term ‘ratio’ is the relative magnitudes of two quantities (usually expressed as a quotient (the result of division).

In a scale of the ‘order of magnitude’ type, there is an exponential change of plus-or-minus 1 in the value of a quantity or unit along the continuum.

Any whole number can be an order of magnitude, because any whole number can be radix/base.

In a linear scale, the fixed ratio is one. In a non-linear scale the fixed ratio is not one. An order of magnitude is a number assigned to the ratio of quantities. If the ratio of quantities at each interval is one, then a linear scale exists. If it is not one, then a non-linear scale exists.

Mathematically, the logarithmic scale is used to calculate orders of magnitude.

If the amount being scaled is 10, and the scale is the base 10 exponent being applied to this amount, then to be an order of magnitude greater is to be 10x (times) as large. Such differences in order of magnitude can be measured on the logarithmic scale in “decades” (i.e. factors of ten). Therein, if there are two quantities are of the same order of magnitude, and if one is less than 10 times as large as the other, then the number of magnitudes that the quantities differ is specified to within a power of 10.

The ‘order of magnitude’ of a scale is the constant factor (ratio) used in division or multiplication to increment a value on the scale.

1. “One order of magnitude more than a given value” - means the multiplication of a given value by the factor (a.k.a., power) of the scale. 100 is an order of magnitude larger than 10. (102 > 101)
2. “One order of magnitude less than a given value” - means the division of a given value by the factor (a.k.a., power) of the scale.

When the ratio/factor is 10, then:

1. One order of magnitude more than 1, is 10 (101); and, one order of magnitude less than 1, is 0.1.
2. Six orders of magnitude more than 1 is 1,000,000 (a million or 106).
3. A value growing by four orders of magnitude implies it has grown by a factor of 10,000 or 104.
4. The order of magnitude of a final number is the number of powers of 10 contained in the number. The number of powers of 10 contained in 10000 is 104.

5.13.6.2 In concern to estimation

Order of magnitude means a number’s nearest power [of some base]. If the magnitude of order is 10, then this means a number’s nearest power of ten.

5.13.6.3 In concern to the term as a degree in an ‘order of magnitude’ scale

An order of magnitude is a degree, or a degree change, in a continuum of size or quantity (of measurement). Here, the term ‘magnitude’ is the property of relative size or extent (whether large or small).

- “Its length was on the order of a meter”.
- “The explosion is of a low order of magnitude.”

5.13.7 Exponents

When a number is multiplied by itself (e.g., 2x2, 4x4, 10x10), the process is called squaring. When a number is multiplied by itself three times (e.g., 2x2x2, 4x4x4, 10x10x10), the process is called cubing. A number multiplied by itself four times has no unique name/label, and is, and thereafter, “raising it to the fourth (fifth, sixth, ...) power”. Squaring is raising to the second power, and cubing is raising to the third power.

The power to which a number is raised is the exponent of that number:

- $\text{base}^{\text{exponent}}$
- $\text{base}^{\text{power}}$

There are two commonly accepted notations for the mathematical operation of “raising to a power”. For example, raising ten to the power of two:

1. 10^2
2. 10^2

A number can be raised to any power, including decimals. The logarithm of a number is the power that some base number must be raised to get that number.

Logarithms compress scales. A linear scale is like a ruler on which each step on the scale adds a unit: to get two meters, one meter is added to one meter; to get three meters, one meter is added onto another, to which another is added. Conversely, on a logarithmic scale, each step on the scale is a multiple of the preceding step.

For example,

- Log10 1 = 0
- Log10 10 = 1
- Log10 100 = 2
- Log10 1000 = 3
- ...

If the logarithms of two numbers are added together, the result is the logarithm of the product (not the sum) of the two numbers. This reflects the fact that steps on a logarithmic scale are multiples.

When a number is multiplied by itself more than once, it can be expressed (in notation) in terms of an "exponent" - the exponent is a little number to the upper right of the number that says, "this is how many times the number has been multiplied by itself". So,2 x 2 x 2 = 23. The "logarithm" is the reverse of this operation. When we ask, "what is log_2(8)" we are asking, "what is the base 2 logarithm of the number 8", or, "how many times did we multiply 2 (the base) to get the number 8". The answer to this question is the exponent from above.

Logarithms are useful in comparing values that vary over a large range.

In mathematics, the logarithm is the inverse operation to exponentiation. That means the logarithm of a number is the exponent to which another fixed number, the base, must be raised to produce that number. In simple cases the logarithm counts factors in multiplication. For example, the base 10 logarithm of 1000 is 3, as 10 to the power 3 is 1000 (1000 = 10 × 10 × 10 = 103); 10 is used as a factor three times. More generally, exponentiation allows any positive real number to be raised to any real power, always producing a positive result, so the logarithm can be calculated for any two positive real numbers b and x where b is not equal to 1. The logarithm of x to base b, denoted logb(x), is the unique real number y such that by = x. For example, log2 64 = 6, as 64 = 26.

- 26 = 64
- 2 is the base
- 6 is the exponent
- 64 is the result of the operation
- Log2 64 = 6 or Logbase x = exponent

On a logarithmic scale, each delineation/division ("tick mark") on the scale is the previous tick mark multiplied by some number (or value). A logarithmic scale is a nonlinear scale used when there is a large range of quantities. It is based on orders of magnitude, rather than a standard linear scale with equal divisions.

A **physical logarithmic scale** is a scale [of measurement], a tool for comparison, that uses the logarithm of a physical quantity instead of the quantity itself.

Exponential logarithmic notation:

Table 11. Measurement > Numbers*: Table showing base 10 counting in exponential and logarithmic form.*

Exponential form	Logarithmic form
10^3=1000	Log10(1000)=Log1000=3
10 is base	

5.13.8 Common positional number/numeral systems

The most common include:

1. **Unary (non-positional)** – every natural number is represented by a corresponding number of symbols. If the symbol "/" is chosen, for example, the number seven would be represented by /////// (seven of the symbol "/"). Any number (i.e., any value) can be represented by combining these digits. The unary [numeral] system can be modified by introducing different symbols for certain values.
2. **Binary (positional)** – two digits (or numerals), 0 or 1. Any number (i.e., any value) can be represented by combining these two digits. This is a base 2 (binary numeral) system. Hence, there are two values. The binary numeral system can be physically implemented with a two-state device.
   - Positional systems obtained by grouping binary digits by three (octal numeral system) or four (hexadecimal numeral system) are commonly used.
3. **Decimal (positional) Arithmetic [numeral system]** – Decimal representation refers exclusively, in common use, to the written numeral system employing numerals as the digits for a radix 10 ("decimal") positional notation. The ten base digits (or numerals): 0,1,2,3,4,5,6,7,8,9 or (0,...,9). Any number (i.e., any value) can be represented by combining these digits. This numeral system is sometimes confusingly called the "arithmetic numeral system". The value assigned to a digit is applied/processed positionally: one's place (1), ten's place (10), hundred's place (100). The system is composed of ten digits, and hence, the position of a digit is used to signify the power of ten that the digit is to be multiplied with: 304 is equivalent to (=) 3×100 + 0×10 + 4×1; or more precisely 3×102 + 0×101 + 4×100.

4. Phi numeral system (positional) – The phi numeral system is also known as: golden ratio base, golden section base, golden mean base, phi-base, base-ϕ, and phinary. It uses the "golden" ratio (symbolized by the Greek letter ϕ, the irrational number (1 + √5)/2 ≈ 1.61803399 symbolized by the Greek letter φ) as its base.
    A. Additive systems - In additive systems numbers are formed by putting together (in a row) several single characters in order of descending value with each character being repeated as many times as required. In expression, this type of system is known as unary/additive notation. Note that additive systems may have additive and subtractive notation. For example, the best known form of additive notation is the Roman system which was similar to the ancient Greek system using letter symbols for powers of 10 and for the intermediate numbers 5, 50 and 500. The symbols used were I for 1, V for 5, X for 10, L for 50, C for 100, D for 500 and M for 1000. Thus 1969 would be written as MDCCCCLXVIIII. A subtractive notation was also used so that, for example, 4 could be written as IV as well as IIII, and 1949 as MDCCCCXLVIIII.
    B. Multiplicative systems - In multiplicative systems there are two kinds of symbols with the symbols of one kind modifying multiplicatively the values of the second kind of symbols.
    C. Arithmetic table

A numeral is a symbol or group of symbols, or a word in a natural language that represents a number. A numeral system (or system of numeration) is a way to write numbers. Roman numerals and tally marks are examples. "11" usually means eleven, but if the numeral system is binary, then "11" means three. Bases categorize numeral systems?

The **decimal point** is the dot (.) placed after the figure representing units in a decimal fraction. A decimal mark is any symbol used to separate the fractional part of a decimal from the whole part. A decimal number usually means there is a decimal point (.) in the number. The decimal point is exactly to the right of the units position and sets the reference standard for all other positions. The number to the left of the decimal is called the "whole number".

For example,

- 17.591
    - 17 is the whole number.
    - Every movement of a digit further left gets 10 times bigger.
    - Every movement of a digit further right gets 10 times smaller.
    - 0.1 = 1/10 = 1 tenth
    - 17.591 = 17 + 5/10 + 9/100 + 1/1000

5.13.8.4 Number system bases

This is just a way of writing a value down.

1. Roman numerals: I (1), V (5), x (10), L (50), C (100), D (500), M (1000)
2. Base 10 is a number system that uses 10 digits: 0-9.
3. Base 2:
4. For bases bigger than 10, capital letters are used as symbols. For example, the sexadecimal (a.k.a., hexadecimal) numeral system (base 16) uses the numerical digits 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F.

The most common bases are binary and hexadecimal (used by computers) and decimal (used by people, because of their ten fingers).

5.13.8.5 Converting [between] bases

In order to convert a decimal number into its representation in a different number base, we have to be able to express the number in terms of powers of the other base. For example, if we wish to convert the decimal number 100 to base 4, we must figure out how to express 100 as the sum of powers of 4.

- 100= (1 * 64) + (2 * 16) + (1 * 4) + (0 * 1)=
- (1 * 4^3) + (2 * 4^2) + (1 * 4^1) + (0 * 4^0)

Then we use the coefficients of the powers of 4 to form the number as represented in base 4:

- 100=1 2 1 0 base 4

5.13.8.6 Numeral system sub-inputs

A numeral system has the following sub-inputs:

1. The symbols: Roman numerals, binary, decimal, fractions, scientific notation, etc.
    - For example, the decimal system has the following symbols: 0,1,2,3,4,5,6,7,8,9, -
2. Rules for combining
    - For example, the decimal system has the following rules:
    - Ordering: -9,-8,-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9
    - Every symbol to the right represents a one value (or count) increase [in the expressed quantity].
    - Combining: 11,12,13,23,33,45,...
    - When a symbol appears to the right of another symbol it is added.
    - Scaling: 10,20,30,100,200,300,1000, 1100,...
    - Every additional digit represents an increasing (left) or decreasing (right) factor (a.k.a., multiple) of ten.

3. Thus, the creation of a logical numeral system: 0,1,2 ,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,30,40, 50,60,70,80,90,100,200,300,...

Numeral systems may be classified by the symbol (and therein, the number of symbols used):

Table 12. Measurement > Numbers*: Table shows base 10 counting symbols in different languages.*

Name	Base number of symbols	Symbols
Greek numerals	10	ō α β γ δ ε ζ η θ ι ...
Western Arabic numerals	10	0 1 2 3 4 5 6 7 8 9
Roman	10	N I II III IV V VI VII VIII IX XL C D M

5.14 Classifying numbers

Numbers can be classified into sets, called 'number systems'. Numbers can be divided into different collections.

5.14.1 Common number types

The concept, 'number', has a three-attribute categorization. There are three common number types (attributes), which have been given the names: nominal, ordinal, and cardinal. In other words, ordinal, cardinal, and nominal numbers are the three [common] attributes of the concept, 'number'.

Cardinal numbers are also known as "counting numbers" and are used to count things. Cardinal numbers are the symbol-unit response to the [numerical] inquiry, "How many?". Ordinal numbers are also known as "position numbers" and are used to place things. Ordinal numbers are the symbol-unit response to the [numerical] inquiry, "Which one?" (or, "What position?").

If there is only the number sequence of set S = {1, 2, 3, ...}. Then, cardinal number of set A" is the number of elements in the set. It is not a specific kind of number (like rational or complex). Similarly, ordinal is not a special number, but merely S applied to ordering. The following question is meaningless, "Is zero an ordinal or cardinal number?" Zero can be the value of the cardinal number of a set. Whether counting starts with 0 is an issue of convenience, though not entirely logical. When you have a list of elements, it is not so practical to start the labeling with 0, since the rank numbers might become adjectives that differ from the proper ranks. However, the tendency would be to associated "level 3" with "the third level", with "third" the adjective of "three". It appears difficult to suppress that tendency. Hence it is better to start lists with label 1.

1. **Ordinal (expresses position)** – order/place (e.g., first, second, third, etc.)
   - Ordinal measures refer to the order or the measure, like the order of the cardinality.
2. **Cardinal (expresses iteration)** – pattern/similarity; whole numbers (e.g., 1,2,3,etc.)
   - Cardinal measures refers to the size of something, "How large?". The interval 'level/scale of measurement' is also known as the cardinal level of measure.

Cardinal and ordinal numbers can be used together in the same argument (i.e., in the same sentence).

Nominal numbers are also known as "categorical numbers" and are used to categorize things. Nominal/ categorical numbers are numeric codes - numerals used for labelling or identification only.

- **Nominal (express category)** – structure through name (naming) and identity (identifying). Nominal numbers can be single (e.g., 2, 4, 5, 3, 1) or grouped. (e.g., 234, 4432, 53, 3344, 153).

5.15 Number-type scales

There are two types of scales, pure scales and compound scales. A bivariate responses with one response ordinal and the other continuous is an example of compound scales. For pure scales, there are several types:

1. Nominal
2. Ordinal
3. Interval
4. Ratio

5.16 Number

Numbers are strings of digits used to indicate magnitude. One number is the designation of a quantity. For clarification, it is useful to have different words for the two expression of the concept 'number'. For example, the Dutch language has different words for number ("getal", as in the list of natural numbers, or the pure decimal system, old-English "tale") and cardinal number ("aantal", the number of elements, English "tally"). Historically, the concept 'number' was synonymous, but it has since been given a broader meaning (i.e., negative, and complex numbers). Hence, in Dutch, the broader meaning of number is called getal, and aantal refers to the cardinal number or count [of something]. Aantal is an arithmetic value, expressed by a word, symbol, or figure, representing a particular quantity used in counting and making calculations, and for showing order.

In measurement applications, numbers measure the presence of a quantity, known as 'magnitude'. There are multiple types of numbers, which fall into two principal categories: counting numbers and scalar numbers.

1. Counting numbers (a.k.a., natural numbers, whole numbers, finite cardinal numbers) – count the

presence of something. Positive whole numbers, which have no fractional parts. There are no negative counting numbers. Counting numbers stop at zero.
2. Scalar numbers - measure some quantity to any desired degree of accuracy.

Math can be applied to both counting and scalar numbers. For counting, 2 apples + 3 apples = [a count of] 5 apples:

Table 13. <u>**Measurement > Numbers**</u>*: Table shows counting and scalar number ordering.*

Set A is counted using ordered {1,2,3...}	Order in A is not relevant	Order in A is relevant
Counting (process; "order some or all")	{1,2,3...}	{1st, 2nd, 3rd, ...}
Cardinal (result) ("how many elements are there?")	{1,2,3,...}	{1,2,3,...}

5.16.1 Numbers as presence and absence

There are *two principle types of numbers* categorized by [the] presence [of existence].

1. The non-zero numbers (presence) - A non-zero number can be used for two purposes: to describe the size of a set, or to describe the position of an element in a sequence. In any number system there is must be more than one symbol used to represent the concept of presence – presence cannot exist without a relationship indicating the presence of two things.
   - For example, the symbols (digits): 1,2,3,4,5, etc.
2. The zero number (absence) - A zero number is used for the absence of a set. In any number system there is only one symbol used to represent the concept of whole absence.
   - For example, the symbol (digit): 0

5.16.2 Numerals used as identifiers and not numbers

The numeral symbols (numerals) are often used as identifiers. Instead of measuring the magnitude of something, or counting some things, these symbols are used to label [objects/events in the real world]. For example, a licensing identification (ID) "number" is not a number; it cannot be used to measure anything, and mathematics does not apply. It is simply a string of symbols/characters that identifies one particular ID from many IDs. Arithmetic cannot be done on the IDs because they are not numbers, they are identifiers (i.e., labels). For efficiency, the selection of identifiers should make logical [conceptual].

Identifying "numbers" (i.e., numeral identifiers) are neither counting nor scalar numbers; instead, they are the symbols used to identify something or act as an identifying label. For example, a phone "number", or id "number" are not scalars.

5.16.2.1 Cardinal numbers (a.k.a., whole numbers, natural numbers, or counting numbers)

In mathematics, cardinal numbers, or cardinals for short, are a generalization of the natural numbers used to measure the cardinality (size or magnitude) of sets. The cardinality of a finite set is a natural number: the number (count) of elements in the set. Cardinal numbers are the natural numbers beginning with 0. The counting numbers are exactly what can be defined formally as the [finite] cardinal numbers.

> **NOTE:** *The transfinite cardinal numbers describe the sizes of infinite sets.*

When we have a set of objects, the cardinality of the set is the number of objects it contains.

The scale of cardinal numbers are (i.e., the cardinal number scale is):

- 0,1,2,3,4,5,6,7,8,9,10,...

Cardinal numbers are integers that can be zero or positive. The usage of a cardinal number assume that the thing(s) being counted are not divisible. There can be 4 of a system, but never 3½ of a system.

Formally, counting numbers are the set of all non-negative integers.

5.17 Number notation

There are various ways that numbers can be written or diagrammed:

1. The number line – a number line is a graphical way to visualize numbers by placing them on a straight line, usually with zero in the middle, positive numbers to the right and negative numbers to the left.
2. Decimal notation (a.k.a., decimal notation) - The most common way to represent real numbers. A string of digits and a decimal point (dot). Digits to the left of the point are increasing powers of ten, those to right are increasing negative powers of ten. For example, 456.65 and -385.109. The numbers on the left side of the dot represent whole numbers, and the numbers on the right side represent decimal values. The point/dot is a decimal signifier – signifying that the numbers coming after it (to the right) are decimal (and not whole) numbers.
   - Note: Different countries officially designate different symbols for the decimal point. In most English-speaking countries, the decimal point is

usually denoted by a period/dot to separate the whole number from its fractional parts. However, in continental Europe, the decimal point is usually denoted with the comma. The choice of symbol for the decimal point affects the choice of symbol for the thousands separator, which is largely used in digit grouping.

- Note: In computing, dot-decimal notation is a string of digits of decimal numbers, each pair separated by a full stop (dot). For example, 192.168.0.1 or 255.255.255.0. The dot in computing is always represented as a dot and never as a comma.

3. Ratios/fractions (percentages; decimals) – a fraction is two quantities written one after the other with a symbol indicating that one is a ratio (or fraction) of the other. For example, 3/4 [of an apple]. Every fraction can also be written as a decimal, and vice versa. A fraction differentiates (or “measures”) parts versus the whole.
   A. XX/YY
   B. XX is the part
   C. YY is the whole
4. Normal form (scientific notation) - a number in normal form consists of two parts: a coefficient and an exponent (power of ten). For example, the distance to the sun is 93000000 miles. This can be more conveniently written as 93×106 miles. 93 is the coefficient and 6 is the exponent.

5.17.1 Whole numbers

While the English number words from 11-100 undergo sound changes, the Chinese numbers remain predictable.

5.17.2 Decimal numbers

Decimal numbers are read with the whole number read first, the word dian3 (to denote the decimal point), and then each decimal place read.

> **NOTE:** *Decimal point, decimal, point, and the word “and” can all be used to express the presence of a decimal point.*

5.17.3 Signed numbers

Signed Numbers are the numbers that need an additional explanation to be determined. Usually we have quantities that can be determined with arithmetic numbers. For example: the road length between two cities (for example: 124 miles), the weight of a bottle of milk (for example: 1 Gallon), the land area (for example: 1000 sq. ft.), ... Those are well determined numbers.

Other times we have quantities that need additional explanation, besides the arithmetic numbers, to be determined. For example if we need to drive 50 miles from the point we are, we need to know in what direction; when we talk about time from the present, we need to know if it is in the past or the future; we can buy or sell an object therefore the money we use will be added or subtracted from the total; ...

5.17.3.1 Positive numbers

A positive number is a number different than zero, preceded by a “+” (plus) sign. Sometimes positive numbers are not preceded by any sign.

If a number is not preceded by a sign it is considered to be a positive number.

- Example of positive numbers: 5; +3; +7; ...

5.17.3.2 Negative numbers

A negative number is a number different than zero, preceded by a “–” (minus) sign. Negative numbers are always preceded by a “–” sign.

5.17.3.3 Absolute value of a number

The absolute value of a number is the value of the number without a sign. The absolute value of a number is written as shown:

- |a| is the absolute value of the number a and has a positive value.
- Example of absolute value of a number: |+9| is equal with 9; |-7| is equal with 7; |0| is equal with 0;.....

5.17.4 Statistics

Statistical methods are basically instruments for processing information. The information that statistical methods process is numerical in nature and derives from one or another of several forms of measurement. The various statistical processes/procedures make different assumptions about the incoming information (as in, measures) they are to process. If the available information incoming for processing is sufficient for the level of statistical operation selected, then the resultant output of that process will provide a high basis for forming rational conclusions. If the statistical operation processes information that violates its input criteria, then the result will be nonsense, and no rational conclusions can be formed.

> **APHORISM:** *Nonsense can still look elegant. Garbage in, garbage out. These are two saying from the language of computer engineers and programmers, an information processing system is only as useful as the accuracy and precision of the information it is fed for processing. A functioning system fed (input) wrong information will output wrong information.*

6 Measurement types and units

6.1 Chemical

6.1 Chemicals and biological organism taxanomical hierarchy

> **CLARIFICATION:** *Taxonomies are simplistic schemes that visually organize the [hierarchical] classification of concepts or objects.*

In biological and also chemical classification, rank is the relative level of a group of elements/organisms (a taxon) in a taxonomical hierarchy:

- Kingdom
- Sub-kingdom
- Infra-kingdom
- Division
- Subdivision
- Infra-division
- Class
- Order
- Family
- Genus
- Species

> **NOTE:** *Biological species and chemical entities can be classified similarly. (Feunang, 2016)*

6.2 Units of capacity

Units of capacity include, for example:

- Ounces
- Cups
- Pints
- Quarts

6.3 Linear density units

Linear density units include, for example:

- Grams per meter (g/m)

6.4 Time scales units

The time scale units include:

1. Nominal time scale (nominal time of day) – AM, PM
    - Categories and no additional information.
2. Ordinal time scale (ordinal time of day) – morning, noon, afternoon, evening, night
    - Indicates direction or order of occurrence; spacing between is uneven.
3. Interval time scale (interval time of day) –12,1,2,3,4, 5,6,7,8,9,10,11,12,1,2,3,4,5,6,7,8,9,10,11,12
    - Equal intervals; difference between 1 and 2 pm is same as difference between 11 and 12 am.
4. Ratio time scale (ratio time of day) - 0,1,2,3,4,5,6,7,8, 9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24
    - 24-hour time has an absolute 0 (midnight); 14 o'clock is twice as long from midnight as 7 o'clock.

6.4.1 Solar time

Timekeeping. Why is a calendar the way it is? Why does the "year" start on January first? //The year of which belief system?

1. Currently, months don't follow the actual lunar cycles. Why are there 24 hours in a day.
2. From ~2:00 onward where the watch is shown he describes all possible time data.

6.4.2 Time and frequency metrology

This area of metrology studies components and their characteristics, especially

- Frequency standards
- Synthesizers
- Oscillators
- Digital clocks

6.4.3 Measurement Unit: Time

A clock is an instrument to indicate, keep, and co-ordinate time. The word clock is derived (via Dutch, Northern French, and Medieval Latin) from the Celtic words clagan and clocca meaning "bell". A silent instrument missing such a striking mechanism has traditionally been known as a timepiece. In general usage today a "clock" refers to any device for measuring and displaying the time.

The timekeeping element in every modern clock is a harmonic oscillator, a physical object (resonator) that vibrates or oscillates repetitively at a precisely constant frequency. This object can be a pendulum, a tuning fork, a quartz crystal, or the vibration of electrons in atoms as they emit microwaves.

Analog clocks usually indicate time using angles. Digital clocks display a numeric representation of time. Two numeric display formats are commonly used on digital clocks: 24-hour notation and 12-hour notation.

Units of human recognizable time include:

1. Years measured in decades (as 10).
2. Year measure in months (as 12).
3. Months measured in dozens (as 12).
4. Month measured in days (as ~30).
5. Days measured in 1440 minutes.
6. Minutes measured in 60 seconds.

7. Etc.

6.4.4 Time measurement system

Time sequence – sequence of data ordered in time; an ordered sequence of data in the time domain. Data that are not time series are usually called cross-section. A time series of cross-sectional data is called panel data – for example, studying weight or income of a particular group ['cohort'] over time is panel data. There are three common graphical representations of time sequenced data:

- Step-wise constant – each step represents a new value. For example, the cost of some item over time.
- Discrete – For example, the number of items sold per day.
- Continuous – For example, a temperature measurement over time.

6.4.5 The daily cycle unit [time]: Clock

In early 21st century society there are two primary unit [time] clocks:

1. The Midday centric clock – This clock is divided into two 12 hour segments. The first 12 hours of the day are signified by "a.m.", which is the acronym for, "anti meridian", which is Latin for, "before midday. The second 12 hours of the day are signified by "p.m.", which is the acronym for "post meridian", which is Latin for "after midday". The two segments are as follows:
   - 12:00am –11:59am is before midday
   - 12:00pm-11:59pm is after midday
   - The 24-hour clock – This clock is known by many names including: Under the 24-hour clock system, the day begins at midnight, 00:00, and the last minute of the day begins at 23:59 and ends at 24:00, which is identical to 00:00 of the following day. 12:00 can only be mid-day. This is the clock unit system universally used the current planetary transportation and logistics system (which has several names, including: Zulu time; Greenwich Mean Time (GMT); and Universal Standard Time).
2. 00:00 and 24:00 are midnight
3. 12:00 is midday
4. 23:59:59 is 1 millisecond before midnight
5. 00:00:01 is 1 millisecond after midnight

Given what is known, the 24-hour clock is more logical and more intuitive than a clock with two specific segments, which adds an additional unit of measure. The 24-hour clock only has the unit 'Time'. In order to have a complete comprehension of a value given by the 12-hour am/pm clock, two units must be given: the time unit, and the a/p m (after/before midday).

> **INSIGHT:** *Time is awareness of change. Time is directionality [of the experience of existence]. It is the unidirectional vector of experience [as consciousness], also idiomatically known as, "the arrow of time". Time is molecular decay.*

6.5 Measurement unit: Human anatomy

Human locomotion - Land area coverage: Average adult human walks about 1 kilometer in about 15 minutes (60m x 15...7

6.6 Measurement unit: Electromagnetics

You may not be able to see it, but this antenna is putting out light (Read: electromagnetic radiation). The reason an antenna is used for radio waves (light) and a filament for visible light is the relative wave-length of the two waves. They are both electro-magnetic radiation (or induction). Radio typically has a frequency between 100kHz and 100GHz, and hence, it has wave lengths between 3mm and 3km. Visible light (ROYGBV) in the green is about a 500nm (or 0.0005mm) wavelength. Visible light can be radiated with an antenna if it is made 250nm long, but this is only recently possible with nanosonic fabrication.

6.7 Measurement unit: Kelvin

Kelvin is temperature, nm is intensity. Then we have spectrum and wavelengths, which are also related to K and nm. The surface temperature of the sun is about 5780 degrees Kelvin, so the peak intensity of solar radiation is about 501 nanometers, which corresponds to the blue-green region of the spectrum. The sun's actual color is white because the range of wavelengths it emits is broad. The sun's light appears yellow to us, however, because of the way Earth's atmosphere scatters light.

Correlated Color Temperature. CCT of a given light source characterizes the temperature of an absolutely black body that would radiate a similar spectrum. The hotter the black body, the higher will be the CCT and the more blue or "cold" will be the light. As an illustration, sunlight has a yellow tint, whereas blue giants - huge stars with high temperature of the surface: 10000K and above (Sirius, for example) - seem bluish even to the naked eye.

6.8 The Color Rendition Index (CRI)

Unfortunately this term is often interpreted wrongly. It characterizes the influence of light source on the perception of an object's color. This parameter shows how correctly a light source with a particular CCT will deliver the color of an illuminated object, compared with an ideal source - an absolutely black body with the same color temperature. To determine the CRI, a set of 8 standard color samples is illuminated with the source and with the light of a back body with the same color temperature. If none of the samples change their color, CRI is equal to 100. The index reduces in inverse proportion to the number of color changes in samples. It is usually believed that a CRI above 80 is good. It is important to know, however, that CRI is calculated for light sources with a particular color temperature. It is not appropriate to compare a 2700K, 82 CRI light source with a 5000K, 85 CRI source.

Also note that CCT and CRI are only defined for full-spectrum light sources. The CRI of monochromatic light is close to zero, and its CCT cannot be calculated. Look at Fig. 15, Fig. 16 - you can see a wide spectrum, starting near 120nm and finishing around 3000nm. In this whole range a clear maximum is present, and most of energy is radiated in a narrow band of wavelengths. Radiation spectrum of a black body can never have the shape of a narrow-band spike, similar to the spectrum of a monochromatic light source, and therefore, calculation of CCT for such sources makes no sense.

The International Commission on Illumination (CIE) suggested a categorization of infrared radiation into the following bands: a) Near-Infrared, NIR / IR-A (700 nm to 1,400 nm or 0.7 μm to 1.4 μm; 215 THz to 430 THz); b) Short-Wavelength Infrared, SWIR / IR-B (1,400 nm to 3,00 nm or 1.4 μm to 3 μm; 100 THz to 215 THz); and c) Mid-Wavelength to Long-Wavelength MWIR / LWIR / IR-C (3,000 nm to 1mm or 3 μm to 1,000 μm; 300 GHz to 100 THz).

1. Kelvin temperature scale
2. Rankine temperature scale
3. Celsius temperature scale

6.9 Measurement unit: Radiation

A.k.a., Units of measurement for radiation.

There are 4 [different] types of [physical] measurement for radiation:

1. Exposure
2. Absorbed dose
3. Dose equivalent
4. Radioactivity

There are 4 [different] types of [physical] measurement for transportation:

1. Distance
2. Speed
3. Movement source
4. Environmental geometry

7 Applicable measurement constants and equations

The seven defined constants are:

- The frequency of the ground-state hyperfine splitting of the caesium-133 atom - $\Delta\nu(^{133}\text{Cs})_{\mathbf{hfs}}$.
- The speed of light in vacuum - c.
- The Planck constant - h.
- The elementary charge - e.
- The Boltzmann constant - k.
- The Avogadro constant - $N_{\mathbf{A}}$.
- The luminous efficacy - $K_{\mathbf{cd}}$.

The seven defined SI units of measurement are:

- s - Second (time)
- M - Meter (distance)
- Kg - Kilogram (mass)
- A - Ampere; formerly known as 'intensity' (I) (electric current)
- K - Kelvin (temperature)
- mol - Mole (amount of substance)
- cd - Candela (intensity of light)

7.1 Units and relationships

Pressure is defined as force/area which is the same as momentum/area/time since F=dp/dt. Momentum flow would be the momentum passing through a unit area per unit time so it's the same units.

- The physical units for heat are Watts (W), Joules/second (J/s) or calories/second (cal/s)
- Heat is measured in watts.
- Heat flow is designated by the symbol q (Watts/m2).
- Electrical power is measured in watts.
- Power = work/time = J/s
- Energy is in joules.
- Electrical power is watts.
- Heat is not energy, but power.

Energy transfers are denoted by:

- Q = Transfer by Heat (J)
- W = Transfer by Work (J)
- q = Specific Transfer by Heat (J/kg)
- w = Specific Transfer by Work (J/kg)
- J = Transfer by Heat per Second, or Power (J/s = Watts)
- $\dot{W}$ = Transfer by Work per Second, or Power (J/s = Watts)

Internal energies and enthalpies are denoted by:

- U = Internal Energy (J)

- u = Specific Internal Energy (J/kg)
- H = U + PV = Enthalpy (J/K)
- h = u + Pv = Specific Enthalpy (J/kg.K)
- $\dot{m}$ = mass flow rate (kg/s)

Single phase:

- Mechanically, power is calculated as leg pressure (Foot Pounds) times speed (Rotating Speed).
- Electrically, power is calculated as leg force (Voltage) times flow (Current).

Dual phase:

- Mechanically, power is calculated as leg pressure (Foot Pounds) times speed (Rotating Speed).
- Electrically, power is calculated as leg force (Voltage) times flow (Current).

Three phase:

- Mechanically, I'm not sure how to calculate the power.
- Electrically, power is calculated as cylinder force (Voltage) times flow (Current) times 1.732 (Square Root of 3).

- Coulomb = amount of electricity
- Coulomb = Ampere x Second
- 1 Coulomb = 1 Ampere • 1 Second
- 1C = 1A • 1s
- C = A • s

And,

- Coulomb = Farad x volt
- Coulomb = 1 Farad • 1 Volt
- 1C = 1F • 1V

7.2 Power

The unit of power is joules per second or J/s when work is measured in joules and time in seconds. The basic unit of power, 1 J/s is called a watt (W), named after James Watt who made important improvements to the steam engine. By definition, a watt is the consumption of one joule of energy per second. 1 W = 1 J/s

- Watts are units: units of power.
- A Watt is the unit of power.
- A Watt can be broken down further to the fundamental units of time, distance and mass.
- A Watt is 1 kg-m^2/s^3 in base SI units
- the power unit is 1 newton-metre/second, or 1 joule/second, this is 1 watt.
- A joule is a unit of work also known as force acting over a distance, i.e., F •d.
- Force is mass times acceleration, i.e., m•a.
- And acceleration is an exponential increase in distance over time, i.e., d/s^2.
- Watt = J/s = F•d/s = m•a•d/s = m•(d/s^2)•d/s = m • d^2 / s^3

- In metric that is kilogram•meter^2/second^3
- Or, generically, mass•distance^2/time^3 or ML^2/T^3
- A watt, as originally defined is volt²/ohm, the current dimensions are V²/R.
- If you use density-velocity-time, a watt = dv^5t^2.

Work Transfer:

- Work (J) = force (N) x distance (m)
- 1 Joule = 1 newton x 1 meter
- In units energy = joules (J)
- Work = joules (J)

Work is not a vector, but force and displacement are vectors.

- W = $^{+}$F x $^{+}$d - when force causes a displacement, work (energy) is positive (F x d = work)
- W = $^{+}$F x $^{-}$d - when force hinders a displacement, work (energy) is negative (F x $^{-}$d = $^{-}$work).
- W = $^{+}$F x ^{0}d - when force results in no displacement, there is no work (F x 0 = 0 work).

Secondly, work (W) is accomplished by a force (f) acting through a distance (d).

$W = \int f_i \cdot dx_i$ *(i.e., Work = Force x Distance)*

For a constant force; the work done formula as force x distance, only applies if you have a constant force:

$W = f_i \cdot \Delta x_i$

NOTE: *Mass is simply how much stuff there is in the object. No matter where you put an object in the universe without taking it apart or breaking it, the mass will always be the same. However, the weight changes. Weight is relative to the field in which the mass exists.*

7.3 Units of energy and power

In order to predict and account for "action", energy is a required quantification. In physics, action is an attribute of the dynamics of a physical/material system. Action is understood as a mathematical functional that takes the trajectory, also called path or history (memory), of the system as its argument and has a real number as its result. Generally, the action takes different values for different paths. Action has the dimensions of [energy]·[time\memory], and its SI unit is joule-second. This is the same unit as that of angular momentum.

Energy and power are measured in a variety of ways depending on the system (and scale) in which the measurement is occurring.

- Energy determined to be contained in a system is called static form of energy (e.g. internal, kinetic, potential energies).
- Dynamic forms of energy come from energy interactions, where energy crosses the system boundary during a process (e.g. heat transfer and work).

Electron volt (eV) is a unit of energy, not voltage. The amount of energy expressed when an electron is accelerated through a potential of 1 volt.

- e = charge on the electron = 1.6×10^{-19}C
- 1V = 1J/C
- eV = $(1.6 \times 10^{-19}\text{C}) \times (1\text{J/C}) = 1.6 \times 10^{-19}$ J

A measure of energy can be expressed/signified in the following ways (i.e., the direct release of energy is measured in units of):

- Electron-volt (eV) - A unit of energy equal to the work done on a charge ("electron") in moving it through a potential difference of one volt. An electron volt is defined as a unit of energy. An electron volt is the energy an electron gains when it is accelerated through a potential difference of one volt. Electron-volt scales: Nuclear energy scales are MeV; Chemical energy scales are eV.
- Joule or jule (J) = a unit of work (energy) equal to the work done when the point of application of a force of one Newton moves a distance of one meter, in the direction of the force. One joule is defined "mechanically" as the energy transferred to an object by the mechanical work of moving it a distance of 1 metre against a force of 1 newton (i.e., netwon-meter).
  - $1 \text{ J} = 1\ ((\text{kg} \cdot \text{m}^2) / \text{s}^2)$
- Watt-seconds or Watt-hour (KWh)
- Calorie
- Radiant energy units
- Heat units (e.g., British thermal units, BTUs)
- Electromagnetic energy units (SI electromagnetic units)
- Nuclear energy units
- Energy - The ability or potential to do work.
- Work - The transfer of energy from one carrier to another.
- No movement = no work.
- Power - The rate at which work is done and energy is transferred.

> **NOTE:** *A joule is a rather small amount of energy, roughly equal to the kinetic energy of a very gently tossed baseball, or to the gravitational energy that you give to a baseball when you lift it by 70 centimeters.*

The more Kilowatts used, the more energy that's being used up.

A kilowatt is 1,000 watts; one watt is the same as one Joule per second (J/s). Which is confusing, since J/s mentions a time frame (second) but it doesn't compare to kWh (which mentions hours, but isn't about time).

Watts cannot be converted to amps, because watts are power and amps are coulombs per second.

If you have at least two of the following, then the missing one can be calculated: amps, volts, watts.

- Watts = amps x volts
- Current = wattage / voltage
- Voltage = wattage / current

Amps are how many electrons flow past a certain point per second. It is equal to one coulomb of charge per second, or 6.24 x 10^18 electrons per second. Volts is a measure of how much force that each electron is under, which we call "potential". Power (watts) is volts times amps. A few electrons under a lot of potential can supply a lot of power, or a lot of electrons at a low potential can supply the same power.

7.4 Energy and work relationship

Energy is substance-like, and work is a transfer mode of that substance. However, energy and work are the same unit of measure although they are not necessarily measuring the same thing.

- Linear kinetics
  - Work = Δtotal mechanical energy
  - Assuming a rigid body that cannot store elastic energy:
  - $Fd = \Delta(.5mv^2 + mgh)$
  - $Fd = \Delta.5mv^2 + \Delta mgh$
- F = ma
  - Work = $m(.5v^2)$
- Angular kinetics
  - Work = Δenergy
  - $Fd = \Delta.5mv^2$
  - $\tau\Theta = \Delta.5I\omega^2$

A watt is a watt is a watt whether it's electrical or mechanical or chemical.

> **QUESTION:** *How much energy is the something (e.g., a bulb) using? That depends on time -- how long it is operating.*

7.5 Kinetic energy systems

- Energy = .5 mass (m) · velocity $(v)^2$

7.6 Potential energy

- Potential energy is often thought of as "stored" kinetic energy, meaning that bodies remain stationary in a potential field while held in place by some force, and upon change in this force (such as breaking the twig holding an apple, or breaking the bond between two atoms), potential energy is converted to kinetic form (the apple "falls" or the molecule "dissociates").
- Gravitational potential energy
  - Energy = mass (m) · gravity (g) · height (h)
- Units: Joules

Gravitational potential energy - energy contained in an object due to its vertical position above the plane of the Earth.

- Gravitational potential energy (PE) = m x g x h
- Where m=mass, g = gravitational constant $9.8 m/s^2$, h=height
- g is known as the gravitational constant. It measures the strength of the Earth's gravitational pull on falling objects. Falling objects accelerate downwards at a rate of $9.8 m/s^2$

Gravitational potential - potential energy per mass.

- PE/mass = (m x g x h) / m

Gravity analogy:

1. Two points in space at the same height\coordinate have zero potential difference.
2. 2. $\Delta\Phi := \Phi(x_2,t0) - \Phi(x_1,t0)$
   A. A falling rock - A 1 kilogram rock (unit mass) can transfer more gravitational potential energy to kinetic energy if it "falls" off the side of a 100 metre ledge than if it falls off a 10 metre ledge.
   B. A falling electron - Similarly, a 1 coulomb charge (unit charge) can transfers more energy if it "falls" through an electrical potential difference of 100 volts than if it falls through 10 volts.
   C. The rock "falls" through a gravitational potential difference and the coulomb "falls" through an electrical potential difference.

7.7 Total energy

Total energy, E. Energy can generally be divided into two groups:

- Macroscopic: energy a system possesses as a whole with respect to some outside reference frame., such as kinetic energy (KE) and potential energy (PE).
- Microscopic: energy related to the molecular structure of a system and the degree of the molecular activity, and they are independent of an outside reference frame. The sum of all forms of microscopic energy is called the internal energy, U, of the system.

The **internal energy** of a system is comprised of:

- Sensible energy: the portion of internal energy associated with the kinetic energy of molecules (i.e. translational, rotational, and vibrational kinetic energies).
- Latent energy: intermolecular forces between the molecules of a system.
- Chemical (or bond) energy: internal energy associated with atomic bonds in a molecule. During combustion processes, atomic bonds are broken and new ones are formed, altering the internal energy of the system.
- Nuclear energy: energy harnessed from the bonds within the nucleus of an atom.

Mechanical work is defined by the relation w = Fdx, where w = work is done, F is force, x is displacement, and the subscripts i and f denote the initial and final states respectively. Similarly, mechanical power is defined as P = Fdv where P is power delivered and v is velocity. Barring, special energy considerations (e.g. magnetic, chemical, surface-tension, etc ...), the total energy of a system can be expressed as:

- E = U + KE + PE

7.8 Internal energy

Internal Energy (E) measures the energy state of a system as it undergoes chemical and/or physical processes. Like other thermodynamic variables, internal energy exhibits two important properties:

1. It is a state function, and
2. it scales as an extensive.

Being a state function means that E has the following property:

- E = Ef - Ei

The relationship between the internal energy of a system and its heat and work exchange with the surroundings is:

- E = q + w

7.8.1 Energy

- Energy = force x distance
- Force = pressure x area

- Distance = volume / area
- Energy = pressure x volume (psig x cu-in = in-lbs)

7.8.2 Work

Mechanical work is:

- Work is scalar.
- Work is Joules.
- Mechanical work is force through a distance (displacement):
  - W is the work done, F is the force, d is the displacement, and · indicates the dot product.
  - Work (W) = Force (F) · distance (x)
  - W = ∫F • x
  - W = F x d x cosϴ
  - Units: Joules (do not use N.m)
  - Force (newton) = mass x acceleration
  - A force has both magnitude and direction, making it a vector quantity. It is measured in the SI unit of newtons.
- The unit of power is the joule per second (J/s), known as the watt, named confusingly after James Watt.
- The mechanical shaft power P in Watts applied to a generator is given by:
  - P = ωT
  - Wherein, ω is the speed in radians per second and T is the torque in Newton meters.
  - Therein,
  - Work = torque x revolutions

7.8.3 Mechanical energy

Mechanical energy is:

- Mechanical energy = Kinetic energy + Potential energy
- Mechanical energy = 1/2mv^2 + mgh

7.8.4 Mechanical pressure

Mechanical pressure is:

- Pressure is defined as the normal force exerted by a fluid per unit area. Pressure can exist, even if no work is being done -- pressure has units of N/m^2 (Pascal as newtons per meter squared).
- The basic unit of mechanical pressure is the newton per square metre.
- Pressure (P) = force/area
- 1 Pa = 1N/m^2

The pascal (symbol: Pa) is the SI derived unit of pressure used to quantify internal pressure, stress, Young's modulus and ultimate tensile strength. It is defined as one newton per square metre.

NOTE: *The flow of momentum is pressure.*

7.8.5 Mechanical power

- Mechanical power (P) is the quotient of mechanical work (A) by time (t).
- P = mechanical work (A) / time (t) = (F x s) / t
- The SI unit of measurement is watts (W).
- Rotational mechanical power is torque (T) and angular velocity (ω) (see Rotational speed).
- P = Tω

7.8.6 Mechanical and fluid systems

In these systems, 'work' is another word for 'energy'. Work (W) = Force (F) · distance (x)

- Unit of force = Newton
- 1 Newton accelerates a mass of 1 kg. by 1 m/s2 (in case of no friction).
- A mass of 1kg on earth experiences a gravitational force of 9,8 Newton.
- Unit of work (energy) = Joule
- 1 Newton moves an object over 1 meter, the required amount of energy is 1 Joule.

NOTE: *Torque is force at a distance. Torque is a pseudovector (equivalent to a mathematical bivector in three dimension); energy is not. A pseudovector is distinguished it from a true polar vector. The units for torque are Newton-meters. Although this is algebraically the same units as Joules, Joules are generally not appropriate units for torque. Torque is usually given by rFsinθ, not just rF, unless the angle is always 90˚of course because sin90=1.*

7.9 Electrical systems

Energy is a quantity indicating the capacity to do work.

- Energy = Power x Time

Power is the rate at which work is done.

- Power = Energy / Time

Voltage exists if charges are moving [through] a distance. Voltage is electric [potential] energy per unit charge, measured in joules per coulomb (= volts).

- Voltage (V) = *energy* in joules (J) / *charge* in coulombs (C)
- Voltage (V) = joule (J) / coulomb (C)
- 1V = 1J/C
- Potential = the *ability* to do work.
- Electric potential is the ability to do [electrical] work per electric unit.
- Similarly, the electric field is electric force per

charge. E = f/q \ f=qE

Electric potential energy - work required to move a charge.

- $F = (k\ 0_1 0_2)/d^2$

Electric potential - The electric potential Φ refers to a quantity with some numeric value. Expresses the effect of an electric field of source in terms of the location within the electric field.

- Φ = PE / q

Electric potential difference (ΔV) - the difference in electric potential (V) between the final and inital location when work is done upon a charge to change its PE.

- $\Delta V = V_B - V_A$ = work/charge = ΔPE/charge

The analog is:

- Volts (V) = Height or head (H)
- Charge (q) = mass m
- Current I = Δq/Δt = rate of mass flow Δm/Δt
- Power = VI = ghΔm/Δt
- Energy = VIdt = Vq = ghm // Energy is the time integral/sum of power.

7.9.1 Electrical work

Electrical work is:

- We = VI
- V = Voltage
- I = current
- We = VIΔt
- t = time
- Power = Energy/Time
- Energy = Power × Time
- Energy (J) = volts · charge in coulombs
- Power (w) = volts · amps
- The standard unit of electrical power is the Watt, which is defined as an [electric] current of one ampere, pushed by a voltage of one volt.
- Watt or kilowatt (watt/1000)
- Current (I) = charge in coulombs / time in seconds
- 1 W = 1J/s
- 1 kW = 1000 W = 1000 J/s
- 1 MW = 1,000,000 W = 1,000,000 J/s

Electric current is measured in coulombs per second (amperes or amps; A).

- 1 Ampere is equal to 1 Coulombs per second.

Current is rate of change in the electric field:

- current (I) = Δq/Δt
- wherein, q=charge

7.9.2 Volt

The volt is defined as the energy transfer per coulomb of charge as charges move between two points in a circuit.

- V = ΔW / ΔQ
- i.e. energy change per unit charge (so that 1 V = 1 J C-1)

7.9.3 Power

Power is equated in multiple ways:

- Power = energy / time (Units: Watts (J/s))
- Power = pressure x volume/time
- Power = Δwork / Δtime
- Power = (force x Δdistance) / Δtime
- Power = force x velocity
- Power = energy/time
- Power = work/time
- Power = (force x distance)/time
  - Distance/time = speed
- Power = force x (distance/time)
- Power = force x speed

7.9.4 Fluid power system

Power in fluid systems is equated in multiple ways:

- Force (F) = pressure (P) · area (A)
- Pressure (P) = Force (F) / area (A)
- Fluid pressure (P) = force (F) / unit area (A)
- Fluid flow rate (Q) = volume (V) / unit time (A)
- Fluid power = pressure (P) x flow rate (Q)

7.9.5 Fuel systems

Fuel systems: In these systems, energy density is key.

7.9.6 Battery systems

No content here yet.

7.9.7 Pressure system

- Energy = pressure · volume
- Pressure = Force/ area unit

7.10 Unit conversion factors

Data and measurements may be expressed in any units, usually chosen for convenience of size. But when this data is used in physical equations, it must be converted to the units required by the coherent system chosen. Units must also be converted when translating from one coherent system to a different one.

Unit conversions begin with equations which relate sizes of units, for example: 1 meter = 3.28 feet. This equation states that the measurement "1 meter" is equal (equivalent to) the measurement "3.28 feet." To write simply 1=3 would be incorrect.

Equations relating measurements are manipulated by the ordinary rules of algebra, and the units are carried along according to the same rules. For example, if both sides of Eq. (3) are divided by 1 yard, the result is:

- 1 = 3 feet / 1 yard = 3 feet/yard
- 1 = 3 feet/yard

This last expression represents an identity relation for measurements. It is called a 'conversion factor'. In algebra it is often convenient to multiply an expression by another expression which is equal to one. When doing unit conversions, expressions may be multiplied by conversion factors, since they are physically equal to one.

Conversion factors for energy units:

- 1 kWh = 3,413 Btu
- 1 kWh = 3,600,000 joules
- 1 joule = 1 watt-second
- 1 joule = 1 Newton-meter
- 1 Btu = 1,055 joules
- 1 Therm = 100,000 Btu = 29.3 kWh
- 1 calorie = 4.184 joules
- 1 Btu = 252 calories

Conversion factors for power units:

- 1 watt = 1 joule/second
- 1 watt = 3.413 Btu/h
- 1 Btu/h = 0.2931 watt
- 1 kW = 1,000 watts
- 1 megawatt (MW) = 1,000,000 watts
- 1 kW = 3,413 Btu/h
- 1 ton of cooling = 12,000 Btu/h
- 1 horsepower (electric) = 746 watts

Guide for common fuels:

- Natural gas: 1,000 Btu/cu. ft.
- Propane: Between 91,333 Btu/gallon and 93,000 Btu/gallon
- Fuel oil: Between 138,700 Btu/gallon and 140,000 Btu/gallon
- Kerosene: Between 120,000 Btu/gallon and 135,000 Btu/gallon
- Gasoline: Between 114,000 Btu/gallon and 125,000 Btu/gallon
- Coal: 25,000,000 Btu/ton
- Seasoned dense hardwood firewood: Between 21 and 26 million Btu/cord
- Seasoned pine firewood: Between 14 and 16 million Btu/cord

Conversion factors used for measuring natural gas:

- 1 ccf ("centi- cubic feet") = 100 cubic feet
- 1 cubic foot of natural gas = 1,000 Btu = 0.01 Therm
- 1 Therm = 1 ccf of natural gas = 100,000 Btu = 29.3 kWh

Conversion factors for air pressure units:

- 1 atmosphere = 14.7 lb./sq. in. = 760 mm. of mercury = 406.78 in. of water = 101,325 Pascals
- 1 Pascal = 0.00401 in. of water
- 1 lb./sq. in. = 6,894.76 Pascals
- 1 lb./sq. ft. = 47.88 Pascals

NOTE: *In the market, electrical energy is a measurable quantity that can be bought by the kilowatt-hour (KWh).*

NOTE: *Energy density = electron-volt per cubic centimeter of space, or eV/cm^3*

NOTE: *The basic quantity of electric charge is the electron. Conversely, electromagnetic waves have no charge.*

In the SI system of units, the joule (J) is a unit of energy, but the electron-volt (eV) is the traditional unit used in ion-solid interactions: 1 eV is defined as the kinetic energy gained by an electron accelerated through a potential difference of 1V. The electron-volt is a unit of energy. The definition of an electron volt is the kinetic energy a single electron acquires when moving through an electric potential of 1V. The charge on the electron is 1.602x10^{19} J. Commonly used multiples of the electron-volt are the kilo-electron-volt (10^3 eV) and the mega-electron-volt (10^6 eV).

Energy density units for problems involving thermodynamic analysis are typically in the form of joules per mole, where a mole (mol) represents Avogadro's number of particles or molecules: N_A = 6.02 x 10^{23} particles/mol.

Joule as a measure of energy. In particle physics, however, we use something more convenient called electron volt (eV) instead.

An electron-volt (eV) is the energy or work required to move an electron against a potential difference of one volt.

Scholarly references

- Garcia, F., Bertoa, M.F., et al. (2006). *Towards a consistent terminology for software measurement*. Information and Software Technology 48 (2006) 631–644. [biblioteca.uma.es]

- Schadow, G., McDonald, C. J., Suico, J. G., Föhring, U., & Tolxdorff, T. (1999). Units of measure in clinical information systems. Journal of the American Medical Informatics Association : JAMIA, 6(2), 151–162. doi:10.1136/jamia.1999.0060151 [www.ncbi.nlm.nih.gov]
- Feunang, Yannick, et al. (2016) ClassyFire: automated chemical classification with a comprehensive, computable taxonomy. Journal of Cheminforatics. [jcheminf.biomedicalcentral.com]

Book references

- Colingnatus, T. (2018). *A child wants nice and no mean numbers*. ISBN 978-946367275-7 [thomascool.eu]
- Bently, J.P. (2005). *Principles of measurement systems*. Pearson: Prentice Hall. [research.iaun.ac.ir]
- Nicholas, J.V., White, D.R. (2001). *Traceable temperatures: An introduction to temperature, measurement, and calibration*. Wiley.

Online references

- Cheng, L. (2009). *How Language And Math Intersect: Chinese v. English*. Thinking About Thinking. [larrycheng.com]
- Johnson, J. *Schema.Org Measurement Proposal*. W3. Accessed: January 7, 2020. [w3.org]
- *Math Learning Tip: Find An Idea's True Name*. Better Explained. Accessed: January 7, 2020. [betterexplained.com]
- *Solar time*. (2019). Wikipedia. [wikipedia.org]
- Stewart, M. (2016). *Counting down to the new ampere*. Phys.org [phys.org]

TABLES

Table 14. Measurement > Quantity > Length*: Spatial length accounting for function.*

Space Used	Surface area required m^2/person	Number of levels	Project area m^2	Estimated height,m	Volume m^3
Dwelling					
Assembly					
Recreation					
Entertainment					
Storage					
Transportation					
Park					
Waste and water treatment and recycling					
Electrical supply and distription					
Cultivational areas					
Mechanical subysystems					
Communications system					
...					

Table 15. Measurement > Quantity*: Quantities per area unit.*

Quantities	Per area	units	
Density of magnetic induction	Φ/A	per cm^2	
Density of dielectric induction	(Q)/A	per cm^2	
Density of electrification	(x)/A2	per cm^4	
Formula	**Type**	**Unit label**	**Description**
x/T = W	Work or energy	Joule	Quantity of electrification varied with respect to time. In time its quantity changes and that is called work or energy. Note that energy is a derivative and does not have a primary existence.
Φ/T = E	Electromotive force	Volt	Total quantity of magnetism varied with respect to time. A volt is the rate at which magnetism is produced or consumed in an electrical system.
x/T = I,	Magnetomotive force	Ampere	Total quantity of dielectrification (produce or consume a dielectric field) and vary that with respect to time.
Q/T^2=P	Power or activity	Watt	Quantity of electricity (the product of Φ•x=Q) and vary it to the time squared.
Φ/I = L	Magnetic inductance	Henry	Magnetism compared to how much current required to produce it.
x/E = C	Dielectric capacity	Farad	For every quantity of dielectric field there has to be a certain amount of electromotive force that gives rise that field.
E/I = Z	Impedance	OHM	
I/E = Y	Admittance	Siemens	
L/T = R	Resistance, Henry per second	OHM	
C/T = G	Conductance, Farad per second	Siemens	
L • C = T^2 (time^2)	$^2\sqrt{LC} = T = F^{-1}$	Hertz^{-1}	Time rate of energy exchanged from the magnetic and dielectric field as they constantly dump one into another

TABLES

Table 16. Measurement > Electricity: *Electricity and magnetism physical units.*

Physical Units: Electricity And Magnetism						
Quantity and Definition	Electro-static (esu)	emu/esu	Electromagnetic emu	MKS/emu	Rationalized MKS	esu/MKS
Charge (Q)	statcoulomb	1/c	abcoulomb	10	coulomb	c/10
Current I = Q/t	statampere	1/c	abampere	10	ampere	c/10
Potential V = W/Q	statvolt	c	abvolt	10^{-8}	volt	10^8/c2
Resistance R=V/I	statohm	c^2	abohm	10^{-9}	ohm	10^9/c2
Capacitance C = Q/V	statfarad	$1/c^2$	abfarad	10^{-9}	farad	10^6/c
Electric field strength E=F/Q=V/s	dyne/statcoulomb = statvolt/cm	$1/c^2$	abvolt/cm	10^{-6}	volt/meter	10^6/c
Magnetic flux	erg/ statampere	c	maxwell	10^{-8}	weber = volt x sec	10^8/c
Magnetic induction	dyne/ (statamp x cm)	c	gauss	10^{-4}	weber/meter2	10^4/c
Magnetic field intensity	statampere/cm	1/c	oersted	10^3/4pi	ampere/meter	12pi10^7
Inductance	stathenry = statohm x cm	c^2	abhenry	10^{-9}	henry	109/c^2

Table 17. Measurement > Quantity *Sub-conceptualizations (as a classification scheme) of the concept, 'quantity'.*

Sub-concepts [for the concept 'quantity']		Sub-conceptual application
length, l	radius, r	radius of a circle A, r_A or r(A)
	wavelength, lambda	wavelength of the sodium D radiation, λ_D or λ(D; Na)
energ, E	kinetic energy, T	kinetic energy of particle i in a given system, T_i
	heat, Q	heat of vaporization of sample i of water, Q_i
electric charge, Q		electric charge of the proton, e
electric resistance, R		electric resistance of resistor i in a given circuit, R_i
amount-of-substance concetration of entity B, c_B		amount-of-substance concentration of ethanol in wine sample i, c_i(C2H5OH)
number concentration of entity B, C_B		number concentration of erythrocytes in blood sample i, C(Erys; B_i)
Rockwell C hardness (150 kg load), HRC(150 kg)		Rockwell C hardness of steel sample i, HRC_i (150 kg)

Table 18. Measurement > Units: *Energy and power in base formula.*

Type	Symbol	Description	In Water	In Electrical Energy	Base Units
Energy	E	The ability to do work	Power=Current*Pressure (P=Q*H)	Power=Current*Voltage (P=I*V)	kg•m²/s³
Power	P	Rate at which work is done	Energy=Power*Time (E=P*t)	Energy=Power*Time (E=P*t)	kg•m²/s²

TABLES

Table 19. <u>Measurement > Metrological</u>: *Metrological units.*

	Units						
Descriptive Elements	Second (s)	Kilogram (kg)	Candela (C)	Kelvin (K)	Ampere (A)	Meter (m)	Mole (mol)
Measures	**Time**	**Mass**	**Luminous intensity**	**Temperature**	**Current**	**Length**	**Amount of substance**
Requires / Based Upon	Hyperfine-transition frequency of the caesium-133 atom (ΔVCs)	Planck's constant (h)	Luminous efficacy of monochromatic light of frequency 540 x 10^{12}Hz and a radiant intensity of 1/683 watts per steradian (Kcd)	Boltzmann's constant (k)	Charge on the electron (e)	Speed of light in a vacuum (c)	Avogadro's constant (N_A)
Definitions / Constant Used	Duration of 9,192,631,770 cycles of the radiation corresponding to the transition between two hyperfine levels of caesium-133	One kilogram is Planck's constant divided by 6.626 070 15 x 10^{-34} $m^{-2}s$	Luminous intensity of a light source with frequency 540 x 10^{12} Hz and a radiant intensity of 1/683 watts per steradian	Equal to a change in thermal energy of 1.380 649 x 10^{-23} joules	Electric current corresponding to the flow of 1/(1.602 176 634 x 10^{-19}) elementary charges per second	Length of the path traveled by light in a vacuum in 1/299,792,458 seconds	Amount of substance of a system that contains 6.022 140 76 x 10^{23} specified elementary entities

Table 20. <u>Measurement > Energy</u>: *Common units of energy.*

Common Units Of Energy And Power	
Energy	Power
joule	joule/sec
calorie	calorie/min
Btu	Btu/hour
watt-hour	watt
kilowatt-hour	kilowatt
orange	orange/day

Table 21. <u>Measurement > Motion</u>: *Linear and rotational motion as speed and force.*

	Speed	Force
Linear motion	speed s	force f
Rotational motion	angular speed ω	twisting force τ

Table 22. <u>Measurement > Units > Transfer</u>: *Conserved quantities and rates of transfer.*

Conserved Quantity		Rate of Transfer	
Name	Units	Name	Units
energy	joules (J)	power	watts (W)
momentum		force	newtons(N)
angular momentum		torque	newton-meters

Table 23. <u>Measurement > Units</u>: *Linear and rotational work and power.*

System	Work	Power
Linear	W = F x d	P = W/t P = F x d/t = F x v
Rotational	W = T x ϴ	P = W/t P = T x ϴ = T x ω

TABLES

Table 24. Measurement > Units*: Generalized table of units of function.*

Description	Energy	Work	Force	Power	Pressure
Measured in units called			Force & torque are measured	Calculated	
Instrument of measurement is a			Dynamometer		Manometer
Has or does not have subcategories	Yes. Two primary forms (kinetic & potential). Multiple forms and types.	Manager...just joking.	Yes. Mechanical contact forces - normal, applied, friction, tension, spring, resisting. Electromagnetic force. Gravitational force. Nuclear force(s). Mechanical twisting force - torque. In mechanics, forces cause linear motion, torques cause rotational motion. Curved motion has centripetal and centrifugal force (and coriollis force).	Yes. Electric, mechanical, fluid, thermal.	No.
Formula(s)		Work = Force x Displacement	Force = Mass x Acceleration (Or) Force = dP/dt (change in momentum by time)	Power = work done/ time taken	
Definition	Measure of ability to do work. It doesn't mean work is being done, but that work can be done.	Change in energy via force. As a result of application of the force, if the configuration of the system changes, the measure of the same is the work done (force into displacement).	An influence that interacts to change the motion of an object. Cause of change in state of motion.	Rate of energy transfer by doing work. Power is the rate of doing work or expending energy. Rate of work done or the rate of energy release.	
Definition with respect to motion	Energy is the magnitude of stress, introduced in universal medium during work.	Work is the magnitude of distortions, introduced in universal medium about a 3D matter-body.	Force is matter-content times rate of change of work-done or rest mass times acceleration.	Power is temporal rate of work-done during acceleration.	
Value type	Scalar (given that work is scalar). Conserved.	Scalar (scalar but no direction)	Vector (direction) and magnitude	Since Energy and Time are both scalars, Power is a scalar also.	Scalar (magnitude and no direction)
Observable when?		When energy transfers.			
Linear motion		W = FΔ x or W = f x dx		P = Fv	
Rotational motion		W = tΔ0 or w = t x d0		P = tw	
Curved motion					

TABLES

Table 25. Measurement > Dimensionality: *Table shows electrical dimensions.*

Note here that there is disagreement over the naming of the electric field. Steinmetz eliminated the use of the term "electric field", and instead, called it the 'dielectric field'. The usage of the term 'magnetic field' is not in disagreement. In Steinmetz's electrical theory, electricity has to be the product of total magnetization times total dielectrification. If it is just one or the other it is not electricity. Hence, a charged capacitor with a total dielectrification and no total magnetization is not electricity. It is only when the energy of each is exchanged in a cyclic process that electricity is appears. In the days of Franklin, metals were called non-electrics because they destroyed the [di]electric field. Energy can be taken apart and put back together. Dimension - one of a group of properties whose number is necessary and sufficient to determine uniquely each element of a system of entities. The misuse of the word dimensions arrives when the term is defined as directional measurement or number of coordinates (i.e., 3 dimensional space). In reality, space is a single dimension (i.e., there exists, only the dimension of space). Space-time then is the relation of two distinct dimensions: the single dimension of space and the single dimension of time. For instance, velocity is expressed as the ratio of the dimension of space to the dimension of space (distance/time=velocity). Thus, velocity is expressed as a two dimensional relationship. Capacitance is a type of electrical energy storage in the form of field in an enclosed space. This space is typically bounded by two parallel metallic plates or two metallic foils on an intervening insulator or dielectric. A nearly infinite variety of more complex structures can exhibit capacity, as long as a difference in electric potential exists between various areas of the structure. The oscillating [tesla] coil represents one possibility as to a capacitor of more complex form, and will be presented here. All the lines magnetic force are closed upon themselves. All the lines of dielectric force terminate on conductors, but may form closed loops in electromagnetic radiation (EMR). Any line of force cannot just end in space. Inductance represents energy storage in space as a magnetic field. The lines of force orientate themselves in close loops surrounding the axis of current flow (magnetism scraping on the wire) that has given rise to them. The large the space between this current and its images or reflections, the more energy that can be stored in the resulting field. Inductance in electronics is electrical inertia. quantity dimensions vs. space and time as metrical dimensions.

Quantity in undivided form		
q	Total Electrification	Plank
Φ	Total Magnetization (outerspace aspect of dielectricity)	Weber
Ψ	Total dielectrification (innerspace aspect of dielectricity)	Coulomb
Basic relationship		
q/Ψ = Φ	Magnetic induction	Weber
Φ x Ψ = q	Magnetism and dielectricity are the two components of electricity	Plank
q/Φ = Ψ	Dielectric induction	Coulomb
Derivatives of quantity by space, A		
Φ/A =	Density of magnetic induction	per cm^2
Ψ/A =	Density of dielectric induction	per cm^2
q/A^2 =	Density of electrification	per cm^4
Derivatives of quantity by time, t		
q/t = W	Work or Energy *The quantity of electrification varied with respect to time. Energy does not have a primary existence. Energy is a derivative.*	Joule
Φ/t = E	Electromotive force *The quantity of magnetization (magnetic field) varied with respect to time. A 'volt' is the rate at which magnetism is produced or consumed in an electrical system.*	Volt
Ψ/t = I	Magnetomotive force *The quantity of dielectrification varied with respect to time (i.e., a dielectric field is either produced or consumed, and it is varied with respect to time.*	Ampere
q/t^2 = P	Power or/of Activity	Watt
Proportionality		
Φ/I = L	Magnetic inductance	Henry
Ψ/E = C	Dielectric capacity	Farad

TABLES

E/I = Z	Impedance	Ohm
I/E = Y	Admittance	Siemens
Density of decay		
L/T = R	Resistance - *The destruction of energy in an electrical system in Henrys per second.*	Ohm
C/T = G	Conductance - *The creation of energy in an electrical system in Farads per second.*	Siemens Mho
$LxC=t^2$	$^2\sqrt{LC} = t = F^{-1}$ *Frequency of oscillation (time rate between the two fields as they "dump" into one another.*	$Hertz^{-1}$

Table 27. Measurement > Units*: Fundamental (base) quantities, dimensions, and units.*

Dimension type	Name of physical quantity	Unit name	Symbol / Abbreviation
Temporal dimension	Time	Second	s
Linear dimension	Length	Meter (Metre)	m
Matter dimension	Mass	Gram (Gramme)	g
Electric dimension	Electric current	Ampere (formerly known as Intensity)	A
Thermodynamic dimension	Temperature	Kelvin	K
Atomic mass dimension	Atom[ic amount of substance]	Mole	mol
Inductive illumination dimension	Illumination	Candela	cd

Table 26. Measurement > Units*: The expression of kinematical units in terms of units of energy.*

Quantity	Dimension		Conversions
	SI Units	Natural Units	
Mass	Kg	E	1 GeV = 1.8×10^{-27} kg
Length	M	1/E	1 GeV-1 = 0.197×10^{-15} m
Time	S	1/E	1 GeV-1= 6.58×10^{-25} s
Energy	Kg m^2/s^2	E	1 GeV = 1.6×10^{-10} Joules
Momentum	kg x m/s	E	1 GeV = 5.39×10^{-19} kg x m/s
Velocity	m/s	None	1 = 2.998×10^{8} m/s (c)
Angular momentum	kg x m^2/s	None	1 = 1.06×10^{-34} J x s (ħ)
Cross-section	m^2	1/E2	1 GeV^{-2} = 0.389 mb = 0.389×10^{-31} m2
Force	kg x m/s^2	E2	1 GeV2 = 8.19×10^{5} Newton
Charge	C-As	none	charge C=A x s none 1 = 5.28×10^{-19} Coulomb; e=0.303=1.6×10^{-19} C

TABLES

Table 28. Measurement > Units: *The most common SI derived units.*

[name] Derivation (derived quantity)	[label] Unit Name	Unit Symbol	Expression in terms of SI base units
dynamic viscosity	pascal second	Pa s	m^{-1} kg s^{-1}
moment of force	newton metre	N m	m^2 kg s^{-2}
surface tension	newton per metre	N/m	kg s^{-2}
heat flux density, irradiance	watt per square metre	W/m^2	kg s^{-3}
heat capacity, entropy	joule per kelvin	J/K	m^2 kg s^{-2} K^{-1}
specific heat capacity, specific entropy	joule per kilogram kelvin	J/(kg K)	m^2 s^{-2} K^{-1}
specific energy	joule per kilogram	J/kg	m^2 s^{-2}
thermal conductivity	watt per metre kelvin	W/(m K)	m kg s^{-3} K^{-1}
energy density	joule per cubic metre	J/m^3	m^{-1} kg s^{-2}
electric field strength	volt per metre	V/m	m kg s^{-3} A^{-1}
electric charge density	coulomb per cubic metre	C/m^3	m^{-3} s A
electric flux density	coulomb per square metre	C/m^2	m^{-2} s A
permittivity	farad per metre	F/m	m^{-3} kg^{-1} s^4 A^2
permeability	henry per metre	H/m	m kg s^{-2} A^{-2}
molar energy	joule per mole	J/mol	m^2 kg s^{-2} mol^{-1}
molar entropy, molar heat capacity	joule per mole kelvin	J/(mol K)	m^2 kg s^{-2} K^{-1} mol^{-1}
exposure (X and γ rays)	coulomb per kilogram	C/kg	kg^{-1} s A
absorbed dose rate	gray per second	Gy/s	m^2 s^{-3}

Table 29. Measurement > Units: *SI Derived Units (a.k.a., Metric Derived Units).*

[name] Derivation (derived quantity)	[label] Unit Name	Unit Symbol
Area	Square metre	m^2
volume	Cubic meter	m^3
Speed, velocity	Meter per second	m/s
acceleration	Metre per second squared	m/s^2
Wave number	1 per meter	m^{-1}
Density, mass density	Kilogram per cubic meter	kg/m^3
Specific volume	Cubic meter per kilogram	kg/m^3
Current density	Ampere per square meter	A/m^2
Magnetic field strength	Ampere per meter	A/m
Concentration (of amount of substance)	Mole per cubic meter	mol/m^3
luminance	Candela per square meter	cd/m^2

TABLES

Table 30. Measurement > Units*: Examples of SI derived units formed by using the radian and sterdian.*

Quantity	Unit Name	Unit Symbol
angular velocity	radian per second	rad/s
angular acceleration	radian per second squared	rad/s^2
radiant intensity	watt per steradian	W/sr
radiance	watt per square metre steradian	W m^{-2} sr^{-1}

Table 31. Measurement > Units*: The seven defining constants of the new SI and the corresponding units they define.*

Defining constant	Symbol	Numerical value	Unit
Hyperfine splitting of caesium	Δν (133Cs)hfs	9,192,631,770	Hz = s^{-1}
Speed of light in vacuum	c	299,792,458	Hz = s^{-1}
Planck constant	h	6.626070040 × 10^{-34}	J s = kg m^2 s^{-1}
Elementary charge	e	1.6021766208 × 10^{-19}	C = A s
Boltzmann constant	k	1.38064852 × 10^{-23}	J K^{-1} = kg m^2 s−2 K^{-1}
Avogadro constant	N_A	6.022140857 × 10^{23}	mol^{-1}
Luminous efficacy	K_{cd}	683	cd sr W^{-1} = cd sr kg^{-1} m^{-2} s^3
The numerical values are taken from the 2014 CODATA adjustment without the present associated uncertainties (not applicable to Δν(133Cs)hfs and c) and may slightly change by 2018.			

Table 32. Measurement > Units*: Physical units as mechanics.*

Physical units: Mechanics			
Quantity and Definition	Metric cgs	Metric MKS	English PFS
Time	Second	Second	Second
Length	Centimeter	Meter	Foot
Mass	Gram	Kilogram	Slug
Velocity v=d/t	centimeter/second	meter/second	foot/ second
Acceleration a = v/t	centimeter/second^2	meter/second^2	food/ second^2
Force F = ma	gm x cm/ sec^2 = dyne	kg x meter/sec^2 = newton	Pound
Energy (Work) W = fd	gm x cm2/ sec^2 = erg	kg x meter^2/ sec^2 = newton	foot x pound
Power P = W/t	erg/sec	joule/sec = watt	foot x pound/ second
Momentum P = mv	gm x sec = dyne x cm	kg x meter/ sec = N x s	slug x foot/ second
Torque G = Fr	dyne x cm	newton x meter	pound x foot
Frequency	1/sec = hertz	1/sec = hertz	1/sec = hertz

TABLES

Table 33. Measurement > Units: *SI derived units with special names.*

[name] Derivation (derived quantity)	[label] Unit name	Unit Symbol	Expression in terms of other units	Expression in terms of SI base units
plane angle[b]	radian	rad		$m \cdot m^{-1} = 1$
solid angle[b]	Steradian	Sr		$m^2 \cdot m^{-2} = 1$
frequency	Hertz	Hz		s^{-1}
force	newton	N		m kg s^{-2}
pressure, stress	Pascal	Pa	N/m^2	m-1 kg s^{-2}
energy, work quantity of heat	Joule	J	N m	m^2 kg s^{-2}
power, radiant flux	Watt	W	J/s	m2 kg s^{-3}
electric charge, quantity of electricity	Coulomb	C		s A
electric potential, potential difference, electromotive force	volt	V	W/A	m^2 kg s^{-3} A^{-1}
capacitance	farad	F	C/V	m^{-2} kg^{-1} s^4 A^2
electric resistance	ohm	Omega	V/A	m^2 kg s^{-3} A^{-2}
electric conductance	Siemens	S	A/V	m^{-2} kg^{-1} s^3 A^2
magnetic flux	Weber	Wb	V s	m^2 kg s^{-2} A^{-1}
magnetic flux density	Tesla	T	Wb/m2	kg s^{-2} A^{-1}
inductance	Henry	H	Wb/A	m^2 kg s^{-2} A^{-2}
Celsius temperature	Degree Celsius	*C		K
luminous flux	Lumen	Lm	Cd sr	cd $\cdot m^2 \cdot m^{-2}$ = cd
illuminance	Lux	Lx	Lm/m2	cd $\cdot m^2 \cdot m^{-4}$ = cd $\cdot m^{-2}$
activity (of radionuclide)	Becquerel	Bq		s^{-1}
absorbed dose specific energy imparted, kerma	Gray	GY	J/kg	m^2 s^{-2}
dose equivalent	Sievert	Sv	J/kg	m^2 s^{-2}

Table 34. Measurement > Units: *Table of common unit systems.*

[Fundamental] Units in system	[Fundamental] Dimensions of system	Common name of system
Foot-pound-second (FPS)	Length-mass-time	English “system”
Foot-slug-second (FSS)	Length-mass-time	English “system”
Centimeter-gram-second (CGS)	Length-mass-time	Mechanical system
Meter-kilogram-second (MKS)	Length-mass-time	Mechanical system
Meter-Kilogram-second-ampere-kelvin-candela-mole	Length-mass-time-current-temperature-illumiination-amount-of-substance	SI
Meter-Kilogram-second-ampere-kelvin-candela-mole	Length-mass-time-current-temperature-illumiination-amount-of-substance	SI

TABLES

Table 36. Measurement > Units*: SI Units.*

Base Quantity	Base Unit	Symbol [for dimension]	Current SI constants	New SI constants
time	second	s	hyperfine splitting in Cesium-133	same as current SI
length	metre	m	speed of light in vacuum, c	same as current SI
mass	kilogram	kg	mass of international prototype kilogram (IPK)	Planck's constant, h
electric current	Ampere	A	permeability of free space, permittivity of free space	charge of the electron, e
temperature	Kelvin	K	triple point of water, absolute zero	Boltzmann's constant, k
amount of substance	mole	mol	molar mass of Carbon-12	Avogadro constant N_A
luminous intensity	candela	cd	luminous efficacy of a 540 THz source	same as current SI

Table 35. Measurement > Units*: Distance as US and Metric units systems.*

United States System	Metric System
1 mile = 5280 feet	1 kilometer = 1000 meter
1 mile = 1760 yards	1 hectometer = 100 meter
1 rod = 5.5 yards	1 dekameter = 10 meters
1 yard = 3 feet	1 decimeter = 1/10 meter
1 foot = 12 inches	1 centimeter = 1/100 meter

Table 38. Measurement > Unit > Function > Temperature*: Temperatures in celcius and kelvin for important states.*

Name (description)	Celsius	Kelvin
Absolute zero	-273.15 C	0 K
Freezing point of water	0 C	273.15 K
Avg. body temperature	37 C	310.15 K
Boiling point	100 C	373.15 K

Table 37. Measurement > Units*: Derived units.*

Name of quantity	Formula	Derived units
Area	length x breadth	metre-square (m^2)
Volume	length x breadth x height	metre-cubed (m^3)
Speed	distance/time	metre per second ($m\ s^{-1}$)
Pressure	Force/Area	Newton per metre squared (Nm^{-2}) Pascal (Pa)

Table 39. Measurement > Number*: Table showing type of number and its decimal representation.*

Type of number	Decimal Representation
Integer	1.00000000000000000000
Non-repeating fraction	0.25000000000000000000
Repeating fraction	0.12312312312312312312
Irrational number	1.41421356237309504880

TABLES

Table 41. Measurement > Dimensionality: *Order of magnitude in (Dimension: Length; Unit Meter).*

Section	Range (m)		Unit	Examples objects
	≥			
Planck length	-	10^{-35}	ℓ	Quantum
Subatomic	-	10^{-15}	am(10^{-18})	Electron
Atomic and cellular	10^{-15}	10^{-12}	fm	Atomic nucleus, proton, neutron
	10^{-12}	10^{-9}	pm	Wavelength of gamma rays and x-rays, hydrogen atom
	10^{-9}	10^{-6}	nm	DNA helix, virus, wavelength of optical spectrum
Human scale	10^{-6}	10^{-3}	μm	Bacterium, fog water droplet, human hair diameter
	10^{-3}	1	mm	Mosquito, golf ball, domestic cat
	10^{0}	10^{3}	m	Human, automobile, whale, buildings
	10^{3}	10^{6}	km	Mount Everest, length of panama canal, trans-siberian railway, large asteroid
Astronomical	10^{6}	10^{9}	Mm	Moon, Earth, one light-second
	10^{9}	10^{12}	Gm	Sun, one light-minute, earth's orbit
	10^{12}	10^{15}	Tm	Orbits of outer plants, solar system
	10^{15}	10^{18}	Pm	One light-year, distance to Proxima Centauri
	10^{18}	10^{21}	Em	Galactic arm
	10^{21}	10^{24}	Zm	Milky way, distance to Andromeda Galaxy
	10^{24}		Ym	Huge-LQG, Hercules Corona Borealis Great Wall, visible universe

Table 40. Measurement > Number: *Number types.*

Name	Symbol	Meaning
Prime		Prime power factor
Composite		Whole subdivision of a count; for example, 6 is a composite number of 2 x 3
Natural	N	0, 1, 2, 3, 4, ... or 1, 2, 3, 4, ... N0 or N1 are sometimes used
Integer	Z	..., −5, −4, −3, −2, −1, 0, 1, 2, 3, 4, 5, ...
Rational, Ratio[nal], Fraction[able]	Q	>Where a and b are integers and b is not 0 >Perfect squares: √4, √9, √16, √25, √36, √49, √64, √81, √100,..., √256,..., √526, √1024,..., √4096,...)
Irrational, Irratio[nal], Non-fraction[able]	I	Decimal expression is: 1.non-terminal 2.non-repeating (no digit pattern to right of decimal)
Real	R	The limit of a convergent sequence of rational numbers
Complex	C	a + bi where a and b are real numbers and i is a formal square root of −1

TABLES

Table 42. Measurement > Statistics*: Measurement scale types.*

Level of measurement (in scale types)	Characteristics			
	Classification	Order	Equal intervals	True zero point
Nominal	Yes	No	No	No
Ordinal	Yes	Yes	No	No
Interval	Yes	Yes	Yes	No
Ratio	Yes	Yes	Yes	Yes

Table 43. Measurement > Statistics*: Measurement scale types.*

Incremental progress	Measure property	Mathematical operators	Advanced operations	Central tendency
Nominal	Classification, membership	=, !=	Grouping	Mode
Ordinal	Comparison, level	>, <	Sorting	Median
Interval	Difference, affinity	+, -	Yardstick	Mean, deviation
Ratio	Magnitude, amount	*, /	Ratio	Geometric mean, Coefficient of variation

Table 44. Measurement > Statistics*: Classification of scales.*

Classification of scales						
Scale	Operation	Examples	Location	Dispersion	Association	Test
Nominal	Equality	Numbering of objects	Mode			Chi-square
Ordinal	Greater or lesser	Hardness of minerals Street numbers Raw scores	Median	Percentiles	Rank-order correlation	Sign test Run test
Interval	Distance	Temperature: Celsius Position, Time	Arithmetic mean	Standard deviation	Product-moment correlation	t-test F-test
Ratio	Ratio	Numerosity (counts) Length, density Position, time Temperature: Kelvin Loudness: sones Brightness: brils	Geometric mean Harmonic mean	Percent variation		

Table 45. Measurement > Statistics*: Only the ratio scale meets the criteria for all four differentiating properties of a scale of measurement.*

Measurement scales	Indicates difference	Indicates direction of difference	Indicates amount of difference	Absolute zero
Nominal	X			
Ordinal	X	X		
Interval	X	X	X	
Ratio	X	X	X	X

TABLES

Table 46. Measurement > Statistics *Classification of measurement scales based on possible mathematical operations.*

Scale type	Description	Operations	Examples
Nominal	A renaming; can establish equivalence.	=	Colours (red, blue); Team members; Stellar spectral types (O,B,A,F,G,...)
Ordinal	Can establish order	= < >	Moh hardness; Rockwell hardness; Beaufort wind scale; Fahrenheit scales
Interval	Can establish meaningful differences	= < > + -	Date, time of day, year, latitude and longitude, centigrade temperature scale
Metric or ratio	Can establish meaningful ratios	= < > + - /	All SI scales (e.g., length, mass); frequency; thermodynamic temperature
Counting or natural	Counts of objects or events, an integer metric scale	= < > + - /	Apples, tires, birthdays

Table 47. Measurement > Statistics*: Measurement scale types*

Scale type	Level of information	Permissible statistics	Admissible scale transformation	Mathematical structure	Corresponding definition of measurement
Nominal (also denoted as categorical)	Equal/not equal	cell count, mode, contingency correlation, Chi-square	One to one (equality (=))	Standard set structure (unordered)	Assignment of numerals based on rules
Partial order	Order among some but not all categories	Cell count, mode, contingency correlation			
Ordinal	Order among all categories	Median, percentiles	Monotonic increasing (order(<))	Totally ordered set	
Interval	Equal intervals	Mean, standard deviation, correlation, regression, analysis of variance	Positive linear (affine)	Affine line	Measurement as quantification
Ratio	Meaningful zero	All statistics permitted for interval scales plus the following: geometric mean, harmonic mean, coefficient of variation, logarithms	Positive similarities (multiplication)	Field	
Absolute	Numerical count of entities in a given category	Mean, standard deviation, correlation, some forms of regression			

Table 48. Measurement > Statistics*: Scale types.*

Scale type	Characterization	Example (generic	Example (SE)
Nominal	Divides the set of objecvts into categories, with no particular ordering among them	Labeling, classification	Naming of programming language, name of defect type
Ordinal	Divides the set of entities into categories that are ordered	Preference, ranking, difficulty	Ranking of failures (as a measure of failure severity)
Interval	Comparing the differences between values is meaningful	Calendar time, temperature (Farenheit, Celcius)	Beginning and end date of activities (as measures of time distance)
Ratio	There is a meaningful "zero" value, and ratios between values are meaningful.	Length, weight, time intervals, absolute temperature (Kelvin)	Lines of code (as measure of attribute "program length/ size")
Absolute	There are no meaningful transformations of values other than identity	Object count	Count (as measure of attribute "number of lines of code")

TABLES

Table 49. Measurement > Numbers: *Number system scale.*

Number System Sub-name	Real world object	Binary (bi-nary)	Quinary (qui-nary)	Decimal	Sexadecimal a.k.a., hexadecimal (hex)	Base	Names for bases number systems
Base	Stones	two	five	ten	sixteen	2	binary
# of designators (symbols)	Sensation of a stone	2	5	10	16	3	ternary
Digits Increasing count (value), and therein, a base symbolic pattern of increasing orders of magnitude [of that count or value]	No stones	0	0	0	0	4	quaternary
	•	1 (2^0)	1 (5^0)	1 (10^0)	1 (16^0)	5	quinary
	• •	10 (2^1)	2	2	2	6	senary
	• • •	11	3	3	3	7	septenary
	• • • •	100 (2^2)	4	4	4	8	octonary
	• • • • •	101	10 (5^1)	5	5	9	nonary
	• • • • • •	110	11	6	6	10	decimal (denary)
	• • • • • • •	111	12	7	7	11	undenary
	• • • • • • • •	1000 (2^3)	13	8	8	12	duodecimal
	• • • • • • • • •	1001	14	9	9	13	tridecimal
	• • • • • • • • • •	1010	20 (5^2)	10 (10^1)	A	14	quattuordecimal
	• • • • • • • • • • •	1011	21	11	B	15	quindecimal
	• • • • • • • • • • • •	1100	22	12	C	16	sexadecimal
	• • • • • • • • • • • • •	1101	23	13	D	17	septendecimal
	• • • • • • • • • • • • • •	1110	24	14	E	18	octodecimal
	-	1111	30 (5^3)	15	F	19	nonadecimal
	-	10000 (2^4)	31	16	10 (16^1)	20	vigesimal

Table 50. Measurement > Language: *Counting in the English and Chinese languages.*

Written as a decimal (and fraction)	Expression with placement (English). Note, the following words all mean the same thing: "decimal"; "point", and "and".	Expression without placement (Chinese)
1.5 (1 5/10)	one decimal [point] five tenths	one decimal [point] five
3.2 (3 2/10)	three decimal two tenths	three decimal two
1.01 (1 1/100)	one point one hundredth	one decimal zero two
4.975 (4 975/1000)	four and nine hundred seventy-five thousandths	four decimal nine seven eight
5.0016 (5 16/10000)	five and sixteen ten thousandths	five decimal zero zero one six

TABLES

Table 51. **Measurement > Language**: *Linguistic efficiency comparison between numerical written expression in Engels language and Chinese language. The Chinese linguistic expression of numerals is more efficient Some researchers hypothesize that one possible reason some Asian cultures show proficiency in math at an early age ironically has nothing to do with math – it has to do with language. It is easier to learn to count in Chinese than it is in English because it requires learning fewer words.*

Numeral	"English" language		"Chinese" language	
1	one	Ten unique English words	one	Ten unique Chinese words
2	two		two	
3	three		three	
4	four		four	
5	five		five	
6	six		six	
7	seven		seven	
8	eight		eight	
9	nine		nine	
10	ten		ten	
11	eleven	Ten more unique words (total is 20 words)	ten one (or, one ten)	No more unique words (total is 10 words)
12	twelve		ten two	
13	thirteen		ten three	
14	fourteen		ten four	
15	fifteen		ten five	
16	sixteen		ten six	
17	seventeen		ten seven	
18	eighteen		ten eight	
19	nineteen		ten nine	
20	twenty		two ten	
21	twenty one	Eight more unique words (total is 28 words)	two ten one	One more unique word (total is 11 words)
30	thirty		three ten	
40	forty		four ten	
50	fifty		five ten	
60	sixty		six ten	
70	seventy		seven ten	
80	eighty		eight ten	
90	ninety		nine ten	
100	one hundred		one hundred	

TABLES

Table 52. Measurement > Metrology > Semiotics: *Measurement semiotics.*

Percept-ion	Symbols (digits/ letters)	De-notation (numeral/word, numerical signifier)	Con-notation (number/idea)
Mathematics	1 2 3 are digits	153/one hundred fifty three	Visual of a 153 amount
Linguistics	d o g are letters	dog	Visual of a dog
Issue[r]	Identifier	Length	Existent
Mathemat[ics]	123	153/one hundred fifty three	Visual of a 153 amount
Linguist[ics]	dog	dog	Visual of a dog

Table 53. Measurement > Metrology > Properties: *Tabular representation of the measurement of the properties of the objects of model set A. This is 'object oriented' measurement. A class of objects (A) are characterized by the combination of several properties in an object profile (M_1, M_2, m_n).*

Objects of the model set A	Properties			
	M1	M2	•••	mn
a	$M_1(a)$	$M_2(a)$		$M_n(a)$
b	$M_1(b)$	$M_2(b)$		$M_n(b)$
•	•	•		•
•	•	•		•
z	$M_1(z)$	$M_2(z)$		$M_n(z)$

Table 54. Measurement > Method: *Measuring objective and subjective quality-of-life [indicators] based on a focus and method for recording, and then using to predict future, measurement.*

		Intentional Focus of Measurement (is estimation; main criterion)	
		Objective as focused on external non-feelings	*Subjective as focused on feelings*
Method of Measurement (is estimation; subsidiary criterion)	*Objective as external measurement/ estimation*	Focus on external and estimated non-feelings; clearly OWB	-
	Subjective as using subject's self-report	Feelings and other self-reporting data can be objectively studied by externals	Clearly SWB

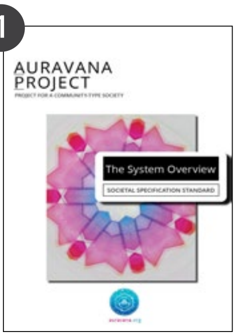
The Auravana Project exists to co-create the emergence of a community-type society through the openly shared development and operation of a information standard, from which is expressed a network of integrated city systems, within which purposefully driven individuals are fulfilled in their development toward a higher potential life experience for themselves and all others. Significant project deliverables include: a societal specification standard and a highly automated, tradeless habitat service operation, which together orient humanity toward fulfillment, wellbeing, and sustainability. The Auravana Project societal standard provides the full specification and explanation for a community-type of society.

This publication is the Material System for a community-type society. A material system describes the organized structuring of a material environment; the material structuring of community. This material system standard identifies the structures, technologies, and other processes constructed and operated in a material environment, and into a planetary ecology. A material system encodes and expresses our resolved decisions. When a decision resolves into action, that action is specified to occur in the material system. Here, behavior influences the environment, and in turn, the environment influences behavior. The coherent integration and open visualization of the material systems is important if creations are to maintain the highest level of fulfillment for all individuals. This standard represents the encoding of decisions into an environment forming lifestyles within a habitat service system. The visualization and simulation of humanity's connected material integrations is essential for maintaining a set of complex, fulfillment-oriented material constructions. As such, the material system details what has been, what is, and what could be constructed [from our information model] into our environment. This specification depicts, through language and symbols, visualization, and simulation, a material environment consisting of a planetary ecology and embedded network of integrated city systems. For anything that is to be constructed in the material system, there is a written part, a drawing part, and a simulation part, which is also how the material system is sub-divided.

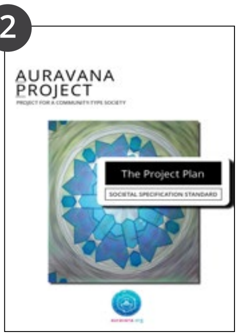
Fundamentally, this standard facilitates individual humans in becoming more aware of who they really are.

All volumes in the societal standard:

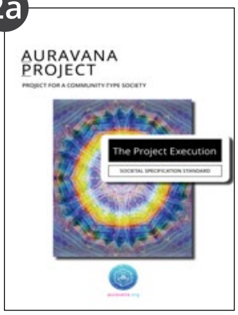
1



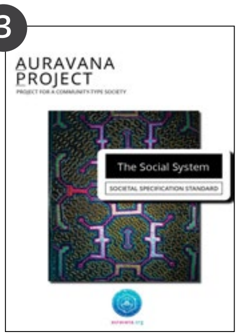
2



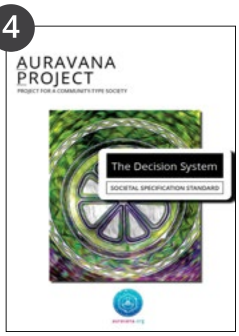
2a



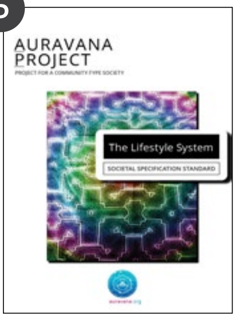
3



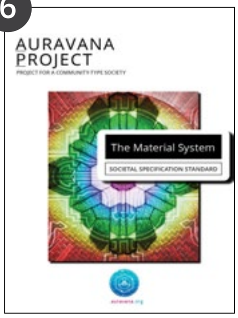
4



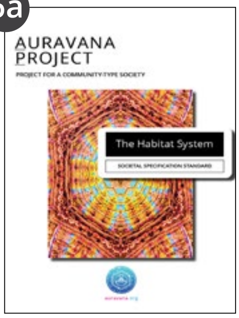
5



6



6a



auravana.org

$7.00
ISBN 979-8-9861436-5-1
50700>
9 798986 143651