Systems Fundamentals to Empower the Systems Analysists

FUNDAMENTAL SYSTEM's PRINCIPLES

04/05/2021

Axel Vanhooren

Download this Article as PDF

Systems are much more than a way to facilitate end-users work, a way to produce products and services or to make profit. Companies, organisations and even our whole society are increasingly systemised. Their entire functioning relies on systems.

Peter Senge: "Today's problems come from yesterday's solutions"

The systems that are being designed today as solutions will create the challenges of tomorrow. And by solving these new challenges, we may easily be busy fixing only the symptoms of the past. Ultimately, this leads to chaos.

It's obvious that understanding and conceiving simple and small systems doesn't require more than everyday skills. Everybody can do this without particular skills and training. However, systems can be critical, larger, complex and unfathomable constructs. The common understanding of 'systems' is way too superficial and definitely insufficient. A deeper understanding and much more advanced competencies become a necessity.

Designing systems requires a solid understanding of the phenomenon of systems, their true nature and their role. We need to be able to think like a system to conceive systems of a superior design.

Briefly described, Systems Analysis – this includes all variants such as Business Analysis, Process Analysis and Functional Analysis – is about studying systems and their environment. Actually, it does much more. Aside from the study, it also evaluates and poses objective diagnosis in systems and in their environment and investigates these problems, conceives new systems or adaptations for them and their environment. Understanding the concept of 'system' is a critical component in this discipline.

For Systems Analysts/Engineers/Designers/Architects, there are

TWO main ROADS to CHAOS:

1) Symptomatic problem solving (most of the time it's the case)
2) Fragmentation (due to focus on local, short term; ignoring long term and big picture)

and TWO ROADS to DESTRUCTION

1) ignorance and arrogance
2) Low ethical values.

This little guide examines different dimensions and aspects of systems. It tries to provide valuable insight constituting a practical fundament to start with.

This Article Will Discuss Different Dimensions of Systems

- Ethical perspective: Role of man-made systems
- Structure: What is a system
- Goal and meaning: Application of engineered systems
- Structure: Co-systems
- Goal, structure & necessity: System hierarchy: supra-system, sub-system
- Necessity: Environment
- Behaviour: Internal Interactions and Influences
- Structure: Core, periphery, foundation and architecture
- Time: Lifespan and Life-cycle
- Casing and Interfaces

This document presents some fundamental insight in systems in a very condensed way. It's presented as a collection of principles, law and thoughts. However, little or nothing will be learned about systems by just passively reading them, and for each statement promptly marking an agreement or disagreement.

A much deeper insight can be acquired by finding examples, by trying to visualise the idea in the statement and by finding arguments supporting or contradicting it. It is also fascinating to think about the implications of each statement. Furthermore, it is inspiring to discover how it affects a system, people or the environment or how it affects our approaches, methodologies and techniques. There is a lot of matter to reflect upon.

Natural systems differ from artificial systems.

A **natural system** is a system that is formed naturally, without human intervention in the design, and consists (mainly) of natural elements. These are elements that have been created by nature. Natural systems are not engineered.

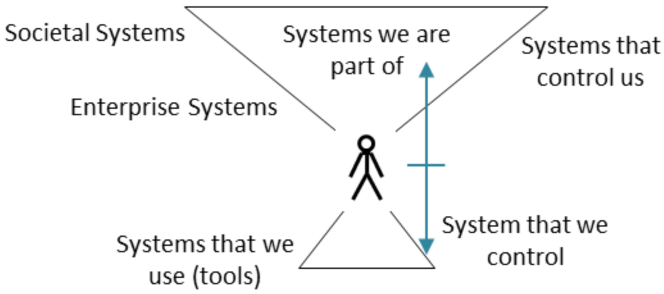
An **artificial system** is a system that has been designed by the human mind and built by humans. It is man-made. It has been engineered. It has been designed. Engineered (artificial) systems are designed with a specific intention and with a purpose in mind. (Future: Systems engineered by computers?)

Discussion point: Have all man-made systems been engineered? Or, is a man-made system always an engineered system?

The focus in this little guide is on engineered systems. Some principles may be only partially true or maybe even not true at all for natural systems. However, much helps to better understand natural systems as well.

Role of man-made systems and an ethical perspective

The world in which we live is composed of systems. These systems allow our society to function. They organise it, they structure it and execute work for it. We mostly design systems to serve our own interests. Although, having this as sole objective is very destructive in the long term. Some systems perform work locally, while others may perform work at sites located far away. Some are compact and others have tentacles reaching distant locations. Systems increase our production capability by performing large volumes of work or by producing huge number of units. They do it faster, more precisely and/or more reliably. Some are designed to function at places which are unreachable by humans or even to operate in environments hostile to humans, reducing the risks for people. Systems literally multiply our capabilities. They allow us to do things we would otherwise be incapable of doing. They give us a tremendous power. This shouldn't be underestimated.



A person uses tools, which are small systems, for his or her activities. The responsibility of the engineer is mainly to design practical systems that do their job. However, an individual, as member, as actor or as customer, is also part of larger and even immense systems. The social security system, the energy network, the financial system, the transport infrastructure, the taxation system, companies and sports clubs are a few examples. These systems define our activities. They guide our behaviour. They influence our decisions and choices. In short, they control us more than we suspect. The 'engineers' of these systems have serious additional ethical questions to take into account. These same ethical questions must be expanded to all living creatures in that system.

People involved in the design of systems - these are not only the engineers - have knowledge, insights, perceptions, impressions, assumptions, intentions, preferences, fears and other emotions, priorities, beliefs and mental models. These elements determine or influence the purpose, role and objectives of systems as well as their design. These ideas and norms become somehow embedded into our systems. There are three main problems.

The **first problem** is simply **functional**. The functions and the logic of a system have to match a relevant objective reality. Therefore, its design has to be based on knowledge and insight reflecting this reality. Thoughts and new ideas have to be aligned with it. But all this insight is commonly not available at hand. The naturally available insight and thoughts are rather subjective, uncertain, partial, superficial, ambiguous, distorted and incoherent. It is certainly not ripe for being implemented. In systems engineering, reality matters much more than impressions, vagueness, assumptions and opinions. Systems designed based on this unreliable and volatile understanding are very likely to create practical problems. A possible consequence can be a shortened system's lifespan. Since insight, thoughts, and preferences can be very vague, unreliable and changing, it is up to Systems Analysis to clarify and stabilise this insight and to transform it into sound knowledge usable for the conception of systems.

By far, most of the time, we solve symptoms (consequences) because that's what is observed. That's what is detected. It is what is experienced as painful. We were too quickly to believe they are the problem, and so we labelled them as such. This leads to chaos.

Everyone can solve simple problems. As soon as the challenge becomes a bit more complicated, undeveloped skills are very likely to lead to oversimplified, superficial, partial and inappropriate solutions. This lack of skills prevents also grasping the consequences, the limits, risks and other negative implications of design choices and decisions. An engineer (or stakeholder) with limited skills is able to think of a simple solution that may create some value. He or she won't even be able to realise that a much more powerful solution can be conceived that would create a much greater value or that it could create new opportunities. The chosen solution will not exploit the opportunity to its full extent. Even if a more advanced solution is presented, someone with limited skills may not grasp its true value. On the contrary, it may instil some apprehension and a feeling of loss of control. He or she may chose for a more modest and lesser valuable solution. Skills are also essential for innovation.

The **second problem** is a matter of **ethics**. A solution or system may function well. But maybe its degree of ethics is questionable. A system is defined and designed accordingly to the moral values of its stakeholders and its designers. Systems can be very powerful and affecting people, a company, its customers or even society as a whole. Their effects are not limited to the intended and visible output. Systems may play a very important role. Therefore, it is crucial to employ superior competencies, higher intelligence, and wisdom and to conceive systems that meet extremely high ethical standards. The same is also true for the invention of technologies and their usage.

Note that the knowledge of some technologies and the ability to apply them, to build a system with it, does not imply the ability to understand and to think like systems or engineer competencies.

For example, adopting a self-centric, or even a human-centric perspective, with as sole criteria the ability to function and to deliver that one result we want, is a ethically questionable and thus pretty scary idea when it concerns either larger or critical systems as well as when it concerns a huge number of systems, products or users.

The **third problem** concerns **abuses**. A system can function well and be very ethical, but possibly it can still be abused. We are not talking here about accidental mistakes. We talk about real deliberate abuses. This includes unethical usages. Depending on the abuse, this weakness, although different, has same end result as the two previous types of problems. The design of systems should thwart abuses.

Some systems may implement or create imbalances or a blind eye can be turned on its harmful effects. Systems may not be sustainable. Four views are particularly interesting.

- The long term has to be considered.
- Systems are designed with an intention. We tend to focus on this intended outcome. Little to no attention is spent to other effects. They are called side-effects. They are not analysed and easily underestimated and even ignored. Some aren't even detected. Since they exist and affect the system and the environment, they may constitute a risk or a cost. They should be identified and studied carefully as any other output.
- A system creates effects, internally and externally, in all directions and in various areas. These effects may create other effects. Or, they may trigger other responses and behaviours which create new effects. It can be considered as an endless chain of effects and reactions. This doesn't mean that the analysis of that chain should be endless.
- Numbers do matter. 1 large chunk may bring about a result of 1000. This 1000 is a large amount and is very visible. And one small element may bring about only a result of 0.1. But if that small element is repeated, if it exists in a large numbers, like 1.000.000 repetitions or occurrences, then the total result is 100.000. The value of 0.1 is thus actually a large number. Small but numerous elements are harder to notice in comparison to a single large element. We shouldn't be fooled.

What is a System?

A system is a view of the mind defining a logical meaningful whole. (A computer is a system, a software application is a system and a computer with the software application is also a system.).

Systems can be microscopic or as large as the Universe or have any size in between.

Some types of systems: natural, environmental, social, physical, abstract, man-made, living, …

A good starting point is to take a look at the definition of 'system' and at some implications of it.

A system is a set of coherently organised, interconnected, interacting and/or collaborating components that form a whole capable of achieving something.

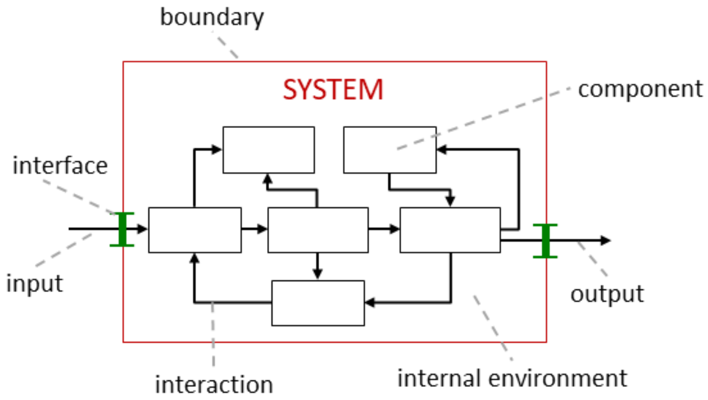
A system is a regularly interacting or independent organised group of elements forming a whole with a specific role or function and obeying to a fixed set of laws.

A system is a dynamic construct capable of creating, transforming or displacing something. It has processes. It has a behaviour. It needs energy and information and/or energy matter.

A system needs energy to perform transformations on information or matter or as product.

A system may need matter to transform it. Not all systems change or move matter.

A system may need information to function or as a product. Not all systems use information.



Basically, a system consists of a set of components. These constituents are interconnected. They interact and influence each other. They form a structure, a network.

The system's functions, capabilities, behaviour and qualities of the system are (mainly) formed by its components and by their interactions and collaboration.

A system always obeys to its own laws. It behaves accordingly to its own logic and characteristics and within its limits.

In man-made systems, this behaviour, qualities and limits have been engineered and built into the system. (Responsibility of the architect/analyst/engineer) (Note: The environment and some more elements or aspects affects this behaviour as well.)

Typically, a system implements elements such as laws, principles and rules, a structure, components, concepts, mechanisms, processes, storage, internal flows, interfaces, executing components, static components, in and out flows, a boundary.

Each component plays a role in the system and contributes to it. A component can bring positive effects and negative effects to the system. It may constitute a limit or a put the system at risk. The overall contribution should be positive. Components that do not contribute to the system should better be removed.

A heterogeneous system contains components of different natures.

A person can also part of a system. He or she can be part of several systems and organisations.

A component can be member or part of a system for a period of time.

A component can be active or inactive in the system.

Components may have to behave very strictly or may behave more independently (some freedom).

Each component has its own purpose, nature, characteristics and lifecycle.

Some parts of the system deal with information, matter or energy or with a combination of them.

A system contains flows of matter, energy and information. Each flow has its own characteristics.

A system may contain storage for matter, energy and information. A storage has its own characteristics.

Some components or sets of components are able to convert matter into energy; energy into movement or vice versa, displaced or transformed matter; one form of energy into another.

Components are connected with fixed connections (two components are attached to each other), through moving connections, through channels (tubes, wires, waves, … guiding flows). (Elastics? springs?)

The connecting element (wire, tube, channel, …) is a component. The connection is an element. (example: a network cable plugged in versus an established network connection)

Some connected components can be connected or disconnected (such as with a switch mechanism).

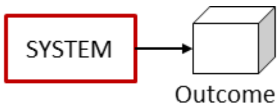
A connection can be interrupted at different levels.

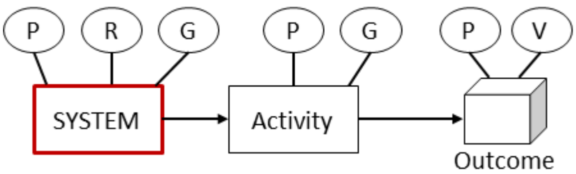
A system has a boundary. This boundary can be well-defined or virtual. It can be made of matter. The boundary can be a variable element. Its shape can be fixed. Or, it can be changed or changing.

The internal environment is the space inside the physical system's boundaries. This environment is not an empty static space which doesn't affect the system. On the contrary, it often plays a role and is very likely to affect the system.

An interface is a mechanism located at the boundary of a system allowing energy, matter or information to enter or to leave the system into the environment or is transported through a medium or connection to other systems. The interface may perform functions such as regulation, reformatting, control, buffering, filtering, transformation of the input or output. It may manage the exchange of these inputs or outputs through protocols with external entities.

Application of Engineered System





A system executes a process, an activity, to produce a result, an effect, an outcome. An active system brings about a change. It creates, transforms and/or displaces matter, energy and/or information.

The outcome or result can be something such as a service, a product, a state, circumstances, an environment, information or energy. The entire outcome includes also all the waste, temporary and intermediate results, visible and invisible results, physical outputs and immaterial effects, desired and undesired results or effects, known and unknown results or effects, … Some of the results may even still reside in the system.

A system is an executor of activities or processes.

In a company or organisation, there are three types of executors: people, machines and computers with software. These basic types can be combined. Examples of this are robots and exoskeletons.

A system can only perform those activities or processes that have been designed and implemented into the system. It works with the given inputs, parameters and active forces, within its limits and within its environment.

Systems can execute entire process from its beginning until the end. Some can execute parts of processes. And some others are used to support the execution of processes. Some can also be used to deploy activities.

A small and simple system implementing a specific function can be qualified as tool (Example: a drill). A person can use a tool to perform activities. Activities can be deployed using systems equipped with a richer set of functions. These activities will then produce the final outcome. (Example: a taxi driver uses a car to deploy a taxi service. A taxi service is more than transporting a person from place A to place B.)

A system is engineered with certain intentions.

A system has a purpose (P). This is the main intended function that has been designed into the system. It is the highest level of synthesis of the logic describing what the system does and is directly linked to the intended result.

Once operational and active, a system plays a role (R) in a network, in a supra-system, in an environment or in a broader context. The role depends of both; of the system and of its context, environment, … .

A system may have to reach some goals (G). Some goals concern the production of output. Other essential goals, sometimes ignored, are related to the system’s life and lifespan (for example: a system seeks to survive.).

An activity, to which a system has to contribute, has a purpose (P), which is the main function of the activity necessary to produce the intended main result.

An activity may have to reach one or more goals (G).

An outcome, also one directly produced by the system, has been conceived (engineered) with a certain functional intent: the purpose (P).

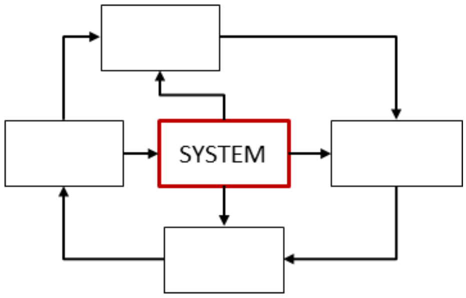
An outcome is expected to have value (V). The value estimated by the customer matters. However, the estimated value can be unreliable when the estimator lacks of insight and competencies. Guessing is not estimating. An outcome may play a critical role in a supra-system. This will increase its value. It can also have undesired effects, which may still be undetected, but which decrease the value. The value is subjective and variable.

The purpose, role and goal of the system; the purpose and goal of the activities and the purpose of the outcome, they all differ from each other.

However, they have to be coherent and respecting each other. If they are conflicting, not the right outcome will be produced; activities may become problematic and/or it can severely affect the system's functioning and its lifespan.

Engineered (man-made, artificial) systems are or seek to be organised, coherent, effective, efficient, reliable, predictable, controlled, managed, adaptable and scalable in order to increase their survival, in order to compete (if necessary) and to increase the chance of a longer lifespan.

Co-Systems



Systems are often connected with other systems: co-systems. They exchange matter, information and energy. They may provide services to each other. These connected systems form networks of systems. Each system has its own nature, purpose, role, goal, logic, behaviour and characteristics.

A modern system is commonly connected with one or more other systems in the same organisation. Systems may also be connected with systems in different organisations (interorganisational systems). They may even form a vast network reaching far beyond the company's boundaries. Some organisations are connected and form a network of organisation.

Systems can be connected with a network and other systems all over the world and even in space.

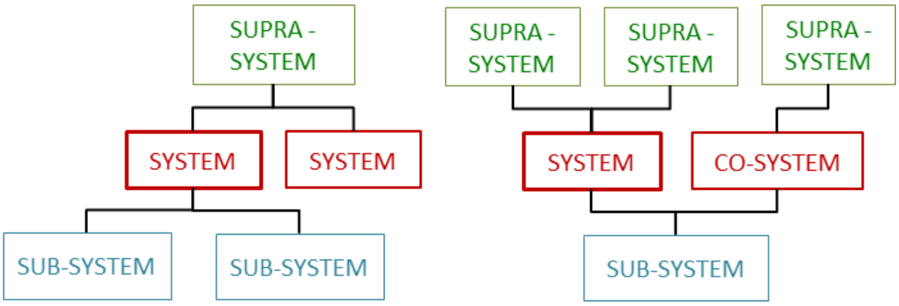
Since different systems have to collaborate with its co-systems, a dysfunction or change in one system may affect the functioning of one or more co-systems.

Co-systems are connected through channels, sometimes equipped with interfaces or other devices.

Co-systems are a source of requirements.

A set of co-systems may form a supra-system (ex. Supply Chain).

System Hierarchy: Supra-System & Sub-Systems



A system may contain one or more sub-systems.

A system is part of a supra-system. Large systems are usually supra-systems.

Supra-systems, systems and sub-systems form a hierarchy of nested systems (± holarchy).

A system and some of its co-systems can be part of the same supra-system. A co-system can also be part of another supra-system.

A system can be part of different supra-systems. And, likewise, a sub-system can be a common constituent of several systems. Or, components and sub-systems can be shared by different systems.

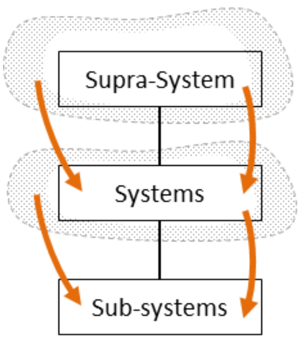
Supra-systems and sub-systems are simply labels indicating a parent system and child-systems in the hierarchy.

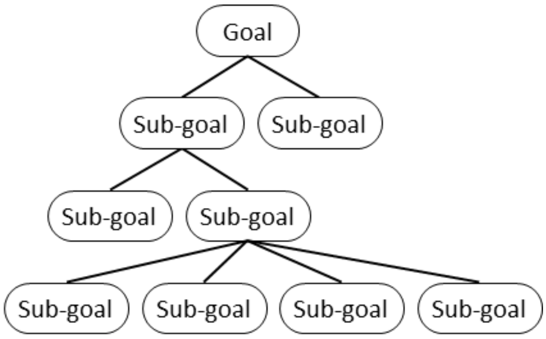
There is an n-m relation between supra-system and systems, and thus also between systems and their sub-systems. But globally spoken, there are more lower-level systems (sub-systems) than higher level systems (supra-systems).

A supra-system has goals and a purpose. The systems have to contribute to them. Similarly, the systems have goals and a purpose and its sub-systems have to contribute to them.

The link between a system and a supra-system can range from very strong to extremely weak. The weaker the link, the lesser the supra-system will impose design requisites on the system and/or the smaller the contribution of the system to the supra-system.

For a supra-system, in order to be able to achieve something, in order to be able to function in an environment, it needs certain functions, capabilities and characteristics. These are mainly implemented by the systems, sub-systems and components. This means that the supra-system and its environment determine some necessities to which its systems, sub-systems and components have to comply with. The supra-system guides the design of its sub-systems and other components top-down.



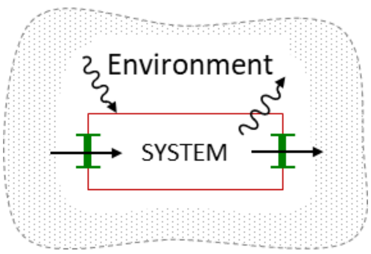


The lower levels of the systems hierarchy and of the systems themselves face the reality and the practical issues. In these lower levels, the requisites that travelled top-down have to be interpreted and/or merged with the possibilities, issues and constraints of this concrete, practical reality. That is where the top-down requisites meet and have to be merged and aligned with bottom-up necessities.

Adapting one component or sub-system may impact the functioning and characteristics of the supra-system. This causes additional risks on local interventions and possible effects such as sub-optimisation, side-effects, and so on.

Understanding the supra-system is a necessity when engineering or adapting a system. Supra-systems have to be studied.

Environment



A physical system exists in an environment.

The environment has certain characteristics.

The environment obeys to principles and laws.

An environment may contain several systems. Or, several systems may have a common environment or a part of it can be common.

Systems can tap from common resources located in the environment.

The environment is often dynamic. Mechanisms can be active in it. Events and changes may take place in it. The entities in it may interact or influence each other.

An environment may be subject to tendencies. Some tendencies are cyclical. Some are irregular. Some tendencies are superficial, with little amplitude, force (value) and have a short “wavelength”. Other tendencies are more profound and have a longer “wavelength”.

The environment is usually heterogeneous. It is a space that may contain physical entities as well as intangible elements.

The environment and the elements in it can be useful (such as resources), lesser useful or not useful to the system. They can be friendly, supportive, collaborative, indifferent, competitive or adversary.

The environment provides things such as space, energy, matter, information, knowledge, money, work force, technologies, laws.

Elements in the environment may be active. Some may move. They may have a lifecycle.

The environment and elements in it may evolve and are likely to do so. This evolution can be slow or fast, erratic or predictable, gradually or sudden, visible or imperceptible, locally or globally, minor or major. For most, this is not a black or white. Rather, it is often a variable phenomenon gliding on a scale.

The environment influences the system.

The system, even by simply being present, influences the environment. It may influence other elements in the environment.

The system interacts with its environment (open systems).

The system’s functioning, the activities deployed with the system, the resource usage and all its outputs may bring about consequences in the environment. They may themselves change the present circumstances and create more consequences.

The system’s interface(s) and the system’s boundary touch the environment.

The system has to/should control what enters the system and what leaves it.

A system can only function in a certain environment and under certain conditions. The system has been and must be engineered or selected in such a way that it can operate in that particular environment and circumstances.

If this is not the case, then either the system has to be adapted to the environment or the environment has to be adapted. Sometimes, it is sounder to adapt the environment.

A system’s environment is stronger than the system.

The environment outlives the system.

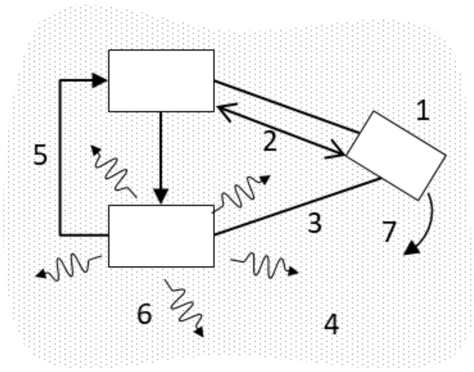
If a system doesn’t respect its environment, then this environment may impede the system’s functioning. It may weaken the system and even kill or destroy it. This may take a certain time. Systems (and designers) must take their environment very seriously.

Therefore the study of the environment is necessary. It is an important source of requirements.

Internal Interactions and Influences

Some influences and interactions between two components happen through a connection between those two components.

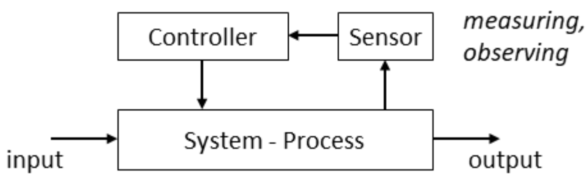
Some influences and interactions happen, not through a connection, but through the internal environment.



The arrangement of the components and the internal environment of the system affect the system's functions, its capabilities, its behaviour and its qualities. It may influence its performances and results.

The influence of one components onto another inside a system depends of factors:

1. position
2. distance between two components
3. connection
4. medium between the components
5. interactions (exchange of energy, material, information, money)
6. influence (intangible, forces, heat, radiation, sound, waves, pressure, force, ...) (nature, volume and strength)
7. movement (direction, speed, force, weight, ...)
8. receptivity and sensibility of the receiving component (protection, shield, used materials, ...)



A system often contains sensors and controllers. They serve to control, regulate and protect the system. A component or a set of components may interact with other components to adjust their behaviours. A system or process is measured or observed. This data is verified against referential data. It has to be within an acceptable range. If it isn't parameters in the system or process are adjusted. (Control Theory). Possibly adjusting parameters won't solve the problem. The reference data may have to be adjusted (.e.g. adjustment of plans). Or the system or process has to be adapted (engineering).

The system's behaviour is a complex phenomenon. It is the result of the behaviour and characteristics of the components and sub-systems, the interactions between them, the system's internal organisation, the system's characteristics and its boundary. Input and interactions with the system's environment will influence the system's behaviour as well.

Components (particularly people) may have to behave very strictly accordingly to a predefined logic or they may have a variable level of freedom. This is may be advantageous for the flexibility. It allows responding to variations and unforeseen events and situations. But it may also be a source of variability and unreliability.

One component in the system may interact with the internal environment and this interaction can be transmitted, transformed or not, onto other components. If this influence is strong enough it may affect the other component.

An inappropriate internal environment and undesired events happening in it may affect the system and its functioning negatively. The internal environment is a special constituent of the system that should not be ignored.

The internal environment is dynamic. Various events may take place in this environment.

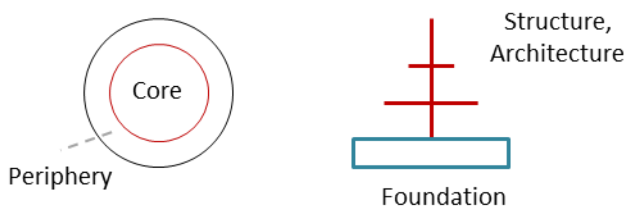
The internal environment, the space between the components, may contain, for example, air, radiation, vapour, gas, insulation, liquid, noise, heat.

The external environment is dynamic. A movement happening in the external environment can be transferred and/or be transformed into the internal environment and affect the system.

Sometimes, the boundary between the external and internal environment is virtual.

In engineered systems, the environment is often protected and even regulated to some degree.

The Core, Periphery, Foundation and Architecture of the System



Engineered systems are or should be internally organised.

The architecture organises the system's internals in a sensible way.

Components or logical units (such as a function) can be put in the right place within the organising structure.

Structure (architecture) provides increased learnability, comprehensibility, ‘diagnosability’, effectiveness, efficiency, flexibility, adaptability, scalability, manageability and decreases risks. Or, a lack of structure decreases those qualities or makes them simply unachievable.

The architecture is expected to be more stable (if well-designed and design is based on a thorough understanding). Nevertheless, it can be changed.

Structure, processes, architecture does NOT necessarily mean or imply rigidity & immutability.

The architecture is often mode difficult to change as such a change is likely to impact a larger portion of the entire system. Changing it without profound overall understanding is risky. Making the same changes without while a clear and logical architecture is absent is probably much more challenging.

There are many different ways to organise a system internally: by subject, by a kind of chronological or other natural order, by role or function, by responsibility, by layer (level of detail), and so on.

The core contains the main mechanism, or a set of important mechanisms, that implements the main function. It deploys the main activity. It performs the greatest transformation or generates the main driving force in the system.

The core can be formed by the logic implementing the main function embodying the purpose of the system. It is often the most advanced logic, the logic that creates the greatest value.

The core is the most critical and very stable part of the system. It is usually the most complex, advanced and valuable part of the system.

The periphery contains smaller, non-critical, complementary and/or supporting systems, components, mechanisms, logic and features. This logic may deal with calculated data and/or extracted data for reporting purposes. It may support more temporary activities.

The periphery contains, generally spoken, not as critical, more variable and transient logic.

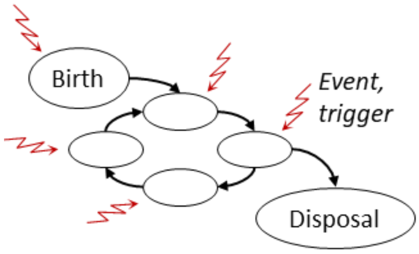
Interfaces and verification of input may also be considered as peripheral, although they have a very important role.

The foundation is formed by elements, features, components, mechanisms, concepts that are rather basic and indivisible, critical, very stable and are likely to be always present. (“very stable” doesn’t mean that they never change)

Systems, parts of systems or components are built on top of the foundation. They make use of these fundamental elements as services, as building blocks, as shared functions.

A system’s internals are organised. This organisation (structure) can be rather static or dynamic.

Lifespan and Life Cycle



A system seeks to survive as long as possible, and preferably to **thrive, to prosper**.

A prosperous system is a system that is healthy (well-being), that is of capable of fully playing its intended role by creating value for the external environment and that gets satisfying rewards for it. Prosperity is a matter of internal status (physical and non-physical) of well-being, alignment with the reality and with the environment and the capability to function and the exchange with the environment and systems, organisations and the actors in it. It's often associated with abundance and growth. It's linked to the creation of valued meaning. Understanding what qualities, what level, where they come from, how they are formed and how they may decline is important.

During its entire lifetime, a system should always be able to **fulfil** the intended **role** well.

A system has to be and to remain **fit for purpose**. Keeping it in that state may require dedicated knowledgeable effort.

A system must possess certain functional qualities and meet a certain level of non-functional qualities. Below this minimum it may make the system dysfunctional. At an even lower level, it may make the system useless.

A system's life can be threatened

- from the inside
- from lack of input or wrong input
- through competition
- inability to evolve
- physical destruction and dismantlement

A system must **maintain an internal health** and seeks to do so (e.g. healing capability in human body). Internal mechanisms, or the lack of some mechanisms, may lead to internal imbalances and undermine the system from within. Some mechanisms may maintain or restore balances.

A system has to be and to remain in a condition of optimal functioning (homeostasis) (balance; within the homeostatic range).

Its life may also be threatened from the inside.

A system requires **special internal mechanisms** aimed at protecting and keeping the system in a good shape (internal controls, balance, harmony, manageability, maintainability, …). Examples of mechanisms are control, buffering, regulating, correction, healing or recovering, maintenance, clean-up, protecting, logging, tracing, detection and warning.

A system that suffers from internal struggles might be misaligned with reality or with the environment. It might be ineffective and inefficient or it is being overexploited. This is not sustainable in the long term. It destroys the system.

Some systems **have to compete against other systems** on performance and on results or they have to compete for food, energy, money or other limited resources. Therefore, they have to be the most effective, the most efficient in producing valuable results of a suitable quality. Because of the **urge to survive, the scarce resources** and the necessity to compete, living organisms developed extremely effective and efficient mechanisms and skills allowing them to survive and to thrive. In nature, this evolution took millions of years of evolution and came at the cost of many failures and deaths

To prolong the system's **lifespan**, a system needs to improve and to evolve. Most systems adapt or are adapted over the course of their lifetime. They evolve.

The system has to be flexible enough to adapt swiftly. The design, and in particular the internal structure, facilitates adaptations. This requires engineering capabilities and a well-designed architecture.

A system has to and seeks to be **aligned with its environment**.

During the course of a system's lifetime, the environment will or may change, the rules may change, events may occur. They may constitute threats the system will have to face.

A system must be able to respond to events and changes that may happen in the environment during its lifetime. However, this doesn't mean that it must respond indiscriminately to any event, change or opportunity. It must possess the ability to do so.

Understanding these **potential events, changes and threats** allows designing a system that is prepared for change.

A system has to be able **to detect changes** and events in order to react early and correctly. Once detected, it has to be able to cope with them. A system has to be responsive, adaptable and probably also scalable.

A system can be equipped with mechanisms allowing detecting environmental changes and events. The earlier the detection occurs, the better it is.

The type of events, changes and threats that may happen during the lifetime of a system depends of the system and of the type of system. A car crash may occur on a car. It is unlikely to occur on a company. A company may go through an acquisition, a merger, a divestiture or a spinoff.

The study of the life of similar systems is a great source for learning these events, changes and threats.

An existing system has a **history**. This is a source for learning the evolution with the reasons (why's) and the causes.

The design of systems has to or should take these types phenomena into account. It should facilitate the response or adaptation.

Events, changes and threats affecting the supra-system may influence its sub-systems. Or, these phenomena may influence the design of the sub-systems.

Changes on a system are necessary to correct, to improve and expand the system, to adapt it to its environment and to increase its capabilities.

“Here is a change. Changes are necessary. Therefore this change is necessary.” Wrong! Not all changes are beneficial and should be applied.

Changes are a **cost** and **imply risks**. A change can be detrimental to the system as well. A good change well-implemented will strengthen the system. A good change badly implemented will weaken the system.

Changes may consist of resolving of issues, adaptations, improvements, expansions. Components and sub-systems can be replaced. Parts of systems may be transferred to another system. New connections (interactions, exchanges, collaboration, …) between systems can be implemented.

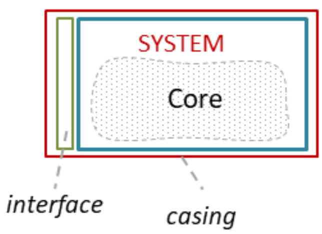
A system’s functional, non-functional qualities can be **adapted**.

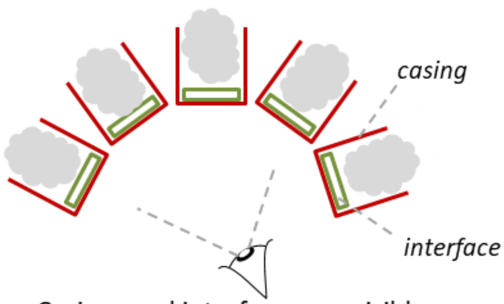
A system can **grow or shrink**. It may require **new or other capabilities**. It can be **restructured**, **split-up** and **merge**.

Adapting one component (or sub-system) may alter the functioning of other components (or connected (sub-)systems) and thus the produced results. It may give **better or worse results**.

Engineered systems can be **artificially terminated**.

Casings and Interfaces





Casings and interfaces are visible
The core of the system, the essence remains hidden (and unknown!) for users

The purpose, the main functions, the usage, the behaviour and some characteristics of systems are commonly known.

The appearance of a system is determined by the interface, the casing and other visible parts.

Non-engineers are presented the casing and the user interface. They are concrete to the end-user. They are visible. They make the system recognisable. These elements are very well known.

The boundary is often formed by a casing. It delimits and protects the system. This casing can be box, case, cover, housing, container, skin or hull. (e.g. Bank: building & front desk; Car: car interior, car body and dashboard, washing machine: casing & control panel, …)

The interface describes some aspects and elements of the internals of a system. It is a great simplification of the actual system's internals. Interfaces hide intention/nally the true complexity of the core of the system. By doing so, it becomes much more comprehensible to the end-user and user-friendly. Their nature also differs a lot from the core of the system. (dashboard versus car engine and other mechanical parts). The interface is not the system! (What's on a computer screen is NOT the software).

Often, usage skills and knowledge of the interface and casing are confused with understanding of the system.

Conclusions

Since the concept '*Systems*' is the core topic and also the output of Systems Analysis, understanding their nature is a foundational competency for this field.

Anyone can design systems, but not everyone can design appropriate and powerful systems solving real problems without creating new problems in the future. It is only by developing the competency of thinking like a system that the latter can be achieved. Understanding systems is a key element to develop this skill.

Systems have been considered from different angles in this article. The dimension of sense, meaning, purpose, role and goal has been briefly discussed. The more static perspective studies the internal structure as well as the outward global organisation and overarching system. The more dynamic perspective considers the systems behaviour. The aspect of sources of prerequisites to which a system should comply with has also concisely been examined. Time dimension concerns the history, the lifecycle and the future of a system, its supra-systems and environment.

Systems provide us a much greater power. But we have to earn this power. Technology and systems must be well understood and their design should be guided by very high ethical values. If we, as society and as individuals, don't grow significantly in this area, we are creating catastrophic future for ourselves.

Axel Vanhooren
Freelance Consultant - IT Re-Thinker - Business Analyst

Download this Article as PDF

OTHER PUBLICATIONS

The Analyst's Red Book

A Visual PDF-Guide about Enterprise Informatics Empowering Analysts and Architects

Download (Latest finished version @ http://analystsredbook.net/)

Download (Latest draft version; “as is”; with more content; maybe only temporarily available)

ARTICLES

Problem Solving: Concepts and Approaches for Systems and Strategies

Rediscovering the Purpose of Systems Analysis (short version)

25 Ways to Disempower Your Business Analyst - STOP Killing the Analyst