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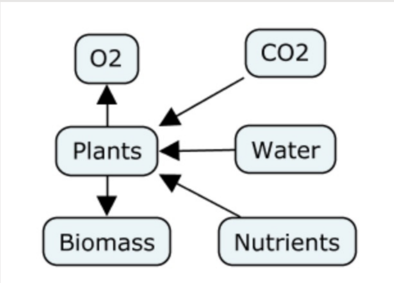
Systems and system modelling

This infocard decribes what is generally meant by a system, various kinds of systems and how they can be visualized in system maps.

A system is a a group of **elements** with some kind of **relation** to each other, static or dynamic.

For example, an **ecosystem** consists of living and dead components which interact with each other in varying time scales.



In a **social** system, it is the relations of people or social animals that are of interest, while a **financial** system is set up to enable the change of funds.

It is often hard to set the **borders** for a certain system, because also systems often interact with each other. Many times this is however necessary to be able to study and describe the system.

Depending on how the system borders are defined, we sometimes need to deal with systems that consist of a large number of elements and relationships. Then it's hard to keep all parts in mind and even harder to communicate with others on matters related to the system using just words or numbers.

Therefore, a number of methods have been developed to visually describe systems and their **behaviour**.

System maps are then used to describe the structure of the system, with its elements and relationships, and **diagrams** to visualise the behaviour of the system, if the dynamics of the system can be quantified.

System types

Systems can be divided into two general types, **static** and **dynamic** systems.

Static systems don't change over time by themselves. A bridge and certain geological formations are examples of fairly stable, static systems.

Many systems are dynamic, which means that the strength or kind of relationship between the elements can show variations, and the number, type or significance of the elements themselves can change over time.

Very dynamic systems with a lot of changing elements and a behaviour that is hard to predict are called **complex** systems.

System models

Few systems can be described in all their detail, so to be able to study and under-stand them, we usually make **models** of them. A model is a generalization and simplification of the system, often expressed mathematically or visually. We also talk about **mental models**, which reflect the understanding a person has of the **structure** and **function** of a system.

Models can be **qualitative** or **quantitative**. Quantitative models can be used for computation and simulation and are based on data, while qualitative models are used to describe the elements and the general principles for the interaction between them.

System maps

A popular way of describing a system is by drawing a **system map**. A system map reflects the understanding of the system and is a useful tool for communication and further development of the system model.

Examples of system maps

Mind maps

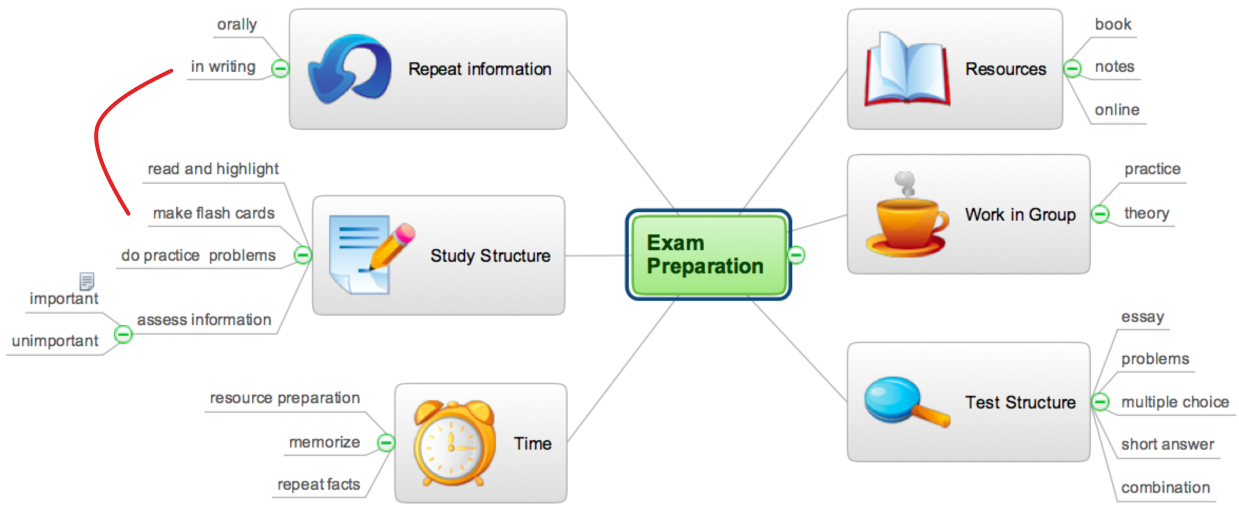
Mind maps can been seen as hierarchical lists in a graphical format. They are not real system maps, but map-like, and more flexible than traditional lists as they can grow organically on a page. They are paper based or digital and can be used for note-taking, brainstorming or outlining, or as general "thinking tools".

Colours and graphics are often used in mind maps, and in many cases links or files can be added as attachments, if the mind map is built using mind mapping software. Also interlinkages between elements ("nodes") are sometimes added, as shown with red in the picture.

The relations between the elements are usually not explained in anyway, and the mind map can therefore be converted into a hierarchical list, as in the example on the right hand side. The graphic version is however said to improve retention compared to a linear list, at least for some people.

Exam preparation

+ *Repeat information*
  - orally
  - in writing
+ *Study structure*
  - read and highlight
  - make flash cards
  - do practice problems
  - access information
    *important
    * unimportant
+ *Time*
  - reduce preparation
  - memorize
  - repeat facts
+ *Resources*
  - book
  - notes
  - online
+ *Work in Group*
  - practice
  - theory etc...



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Causal loop diagrams

Causal loop diagrams are system maps that show both the elements and **what kind of influence** one element has on another, positive or negative. These maps or diagrams contain much more information than maps that just show arrows between elements - often in a way where the only conclusion that the viewer can draw is that everything influences everything.

Causal loops diagrams have arrows that are marked with a plus or minus sign (polarity) depending on if the relation makes the receiving element grow/stronger (**positive feedback**) or shrink/weaker (**negative feedback**).

Causal loop diagrams can be used for analysis, even if we don't know exactly how much one map element influences the other. The analysis usually focuses on finding **reinforcing** (R) or **balancing** (B) **loops**.

Based on this, we can draw conclusions like the ones in the column on the right which are drawn from the causal loop diagram at the bottom of the page.

The casual loop diagram shows that local stakeholders think about their region that:

- there is a strong link between the economy and the social capital of a given village
- the low profitability of small-scale farming stimulates youth emigration and land abandonment
- there is a negative influence of poor infrastructure on economic conditions
- the collapse of the communist regime negatively influenced the social capital in the region
- economic development could lead to short-term financial benefits, but could harm natural resources
- there is a reinforcing feedback loop around poverty, conflict, low social capital, and poor education (R2 in the diagram), which caused rural emigration
- the dual processes of farmland intensification in some areas and abandonment in others lead to a decrease in traditional small-scale farming and consequently negatively affect farmland biodiversity, as well as cultural, regulating, and supporting ecosystem services, and
- forest exploitation for timber and firewood is a threat to forest biodiversity and the ecosystem services provided by forests.

Text from: https://sustainabilitymethods.org/index.php/System_Thinking_%26_Causal_Loop_Diagrams
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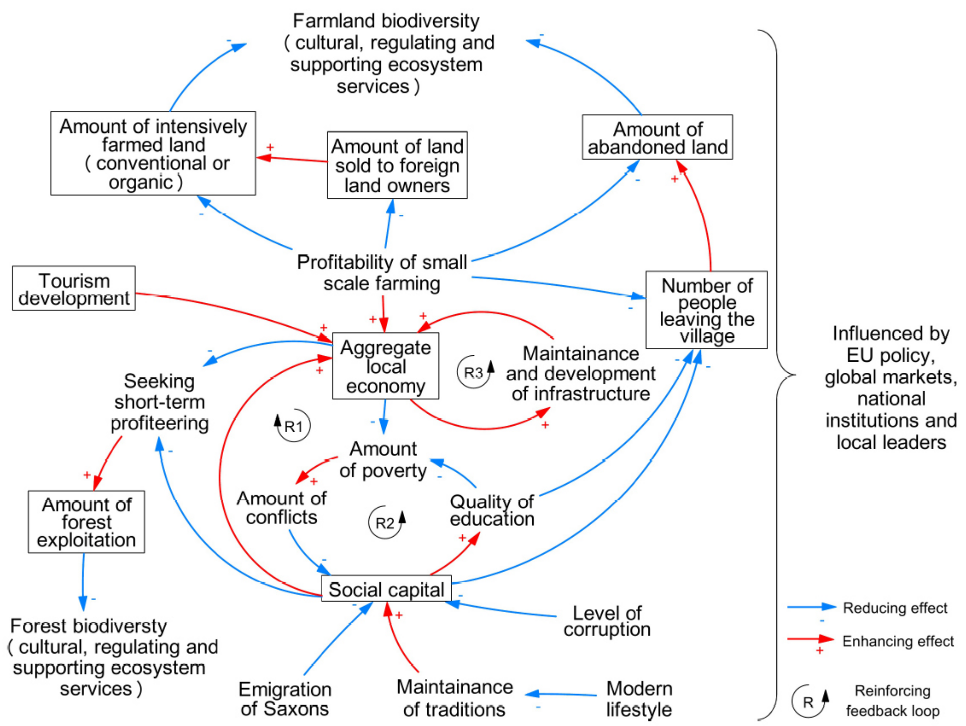

Source: Hanspach et al. 2014. p.5

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Concept maps

In a concept map, the links between the **concepts** (elements) carry a meaning, expressed by a **linking phrase**. The maps are structured in such a way that two concepts linked together by a linking phrase form a **proposition**, a statement of how this part of the system works. When we follow the proposition flow, expressed with direction arrows, more or less natural sentences are formed.

As with mind maps, concept maps can be built on paper or digitally using software. Concept maps are especially well suited for building qualitative knowledge models that reflect the **mental models** that a person or a team has of how a certain system is composed and how it works.

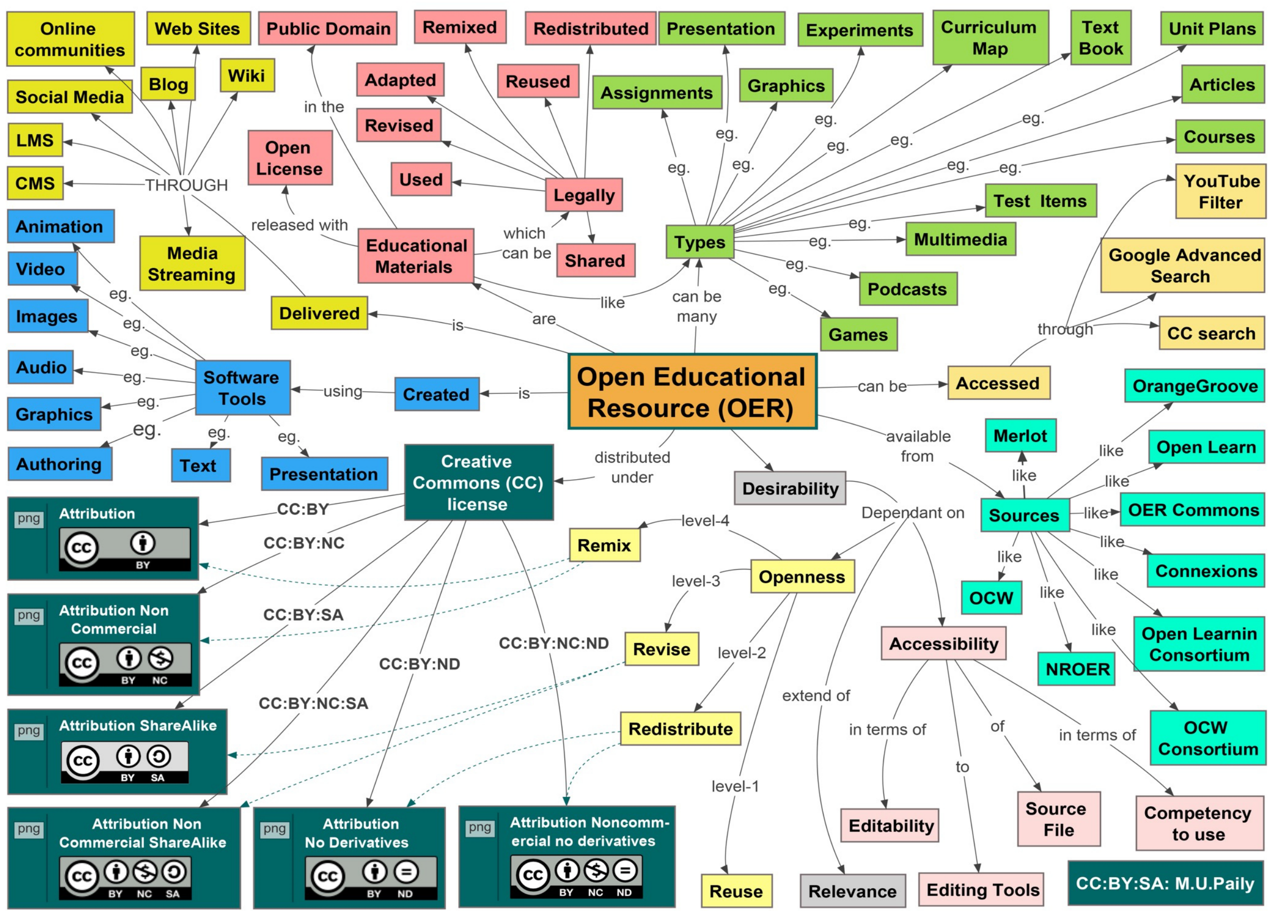
Misconceptions are easy to identify and therefore concept maps are also suitable for evaluating the knowledge levels of students, for example.

If we use a software tool like [CmapTools](), many more functions are added to the basic ones. It is then possible to add annotations, files, multimedia and links to concepts and linking phrases, to link concept maps to each other and to collaborate on the maps in real time. In that way it is possible to build large, easy to access **knowledge repositories**.

The inbuilt presentation tool in CmapTools can be used to present the model in a way that is not overwhelming for the viewer - otherwise a common problem with system maps.

CmapTools is thoroughly documented and the underlying theory of concept mapping is based on [research]().

Concept mapping is proved to be useful as a knowledge visualisation and building tool from primary school onwards.



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Dynamic systems maps

System dynamics (SD) deals with quantitative data and simulations. As for other graphical system mapping methods, also the mapping of dynamic systems have developed its own style, terminology and routines.

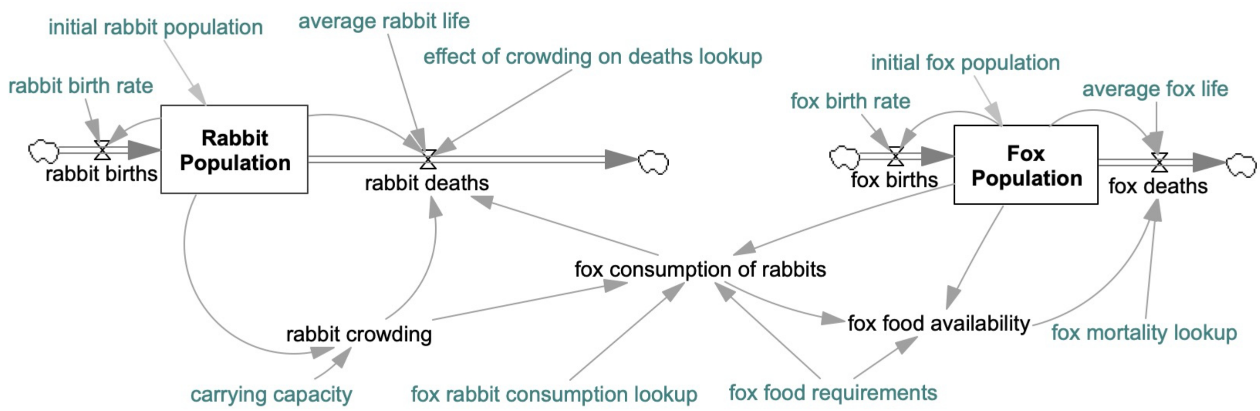
The building of a quantitative system model is often demanding because the data and equations needed for the **simulation** (running) of the model must be reasonably correct for the simulation to give useful results.

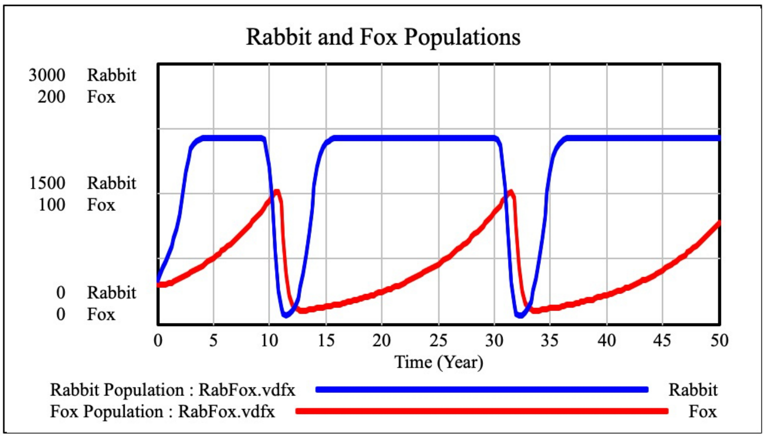
If the system and its behaviour is well known and modelled, a lot can be learned about how to tweak the real system to get it to produce desired results. This goes for industrial systems, ecosystems, traffic systems and other systems where the **states** and the **flows** in various parts of the system can be reliably quantified.

The main principles of mapping a dynamic system in SD software like Vensim consists of adding the **state variable** (the "stock") and connect in- and outgoing flows to it. The flows are regulated by "faucets" depicting the **rate of change**, and the rates of change are in turn determined by various circumstances called **intermediate variables.**

The mathematical parts of the model (the **equations**) are generally not visible to the viewer, but need to be filled in in the background by the modeller, together with initial values for the variables.

When the model is run, results are shown in one or several graphs (or tables) that show what happens to the system over the time period set for the model. By doing several runs with different settings for the variables, the system behaviour can be better understood.





Screenshot from Vensim PLE