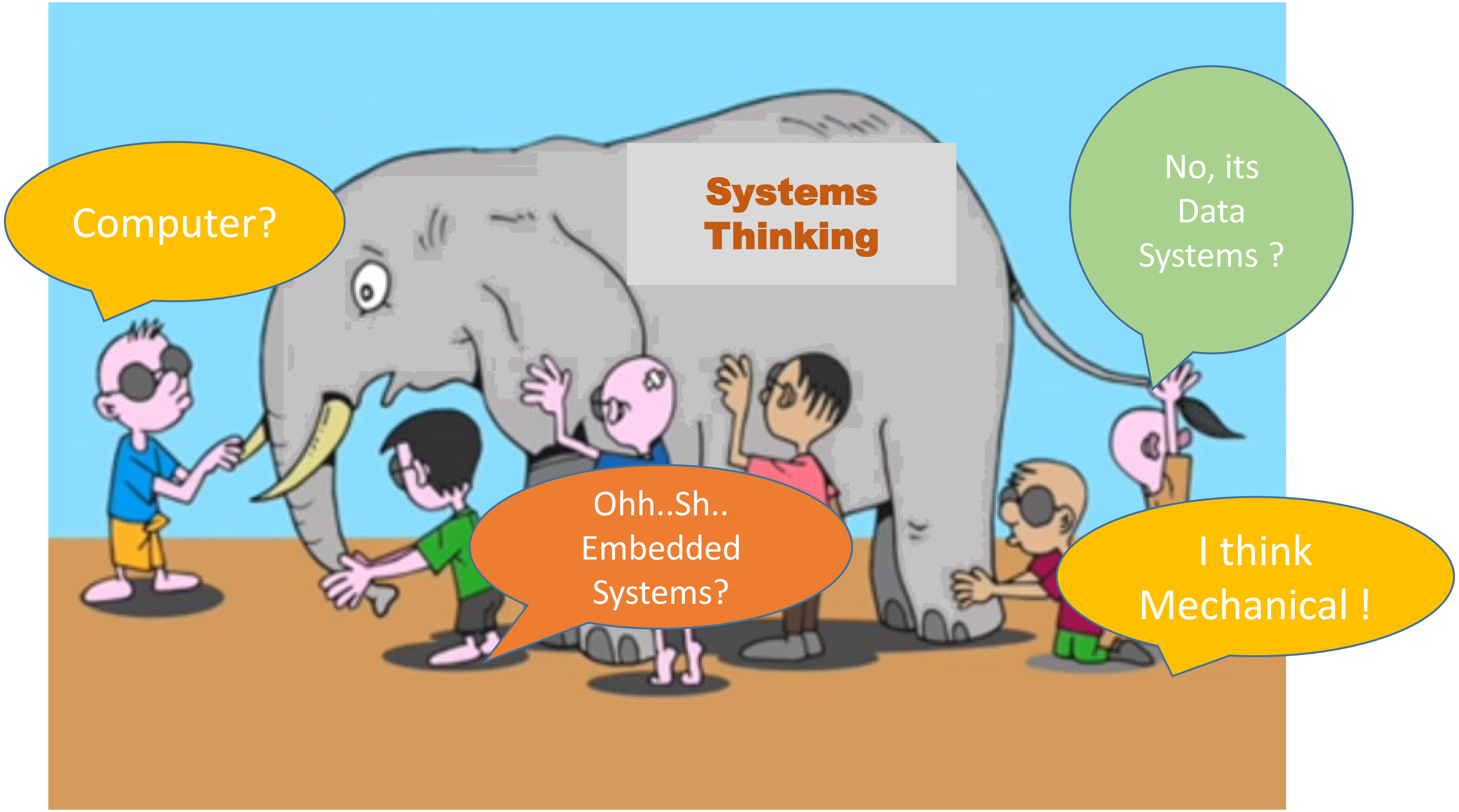
Welcome to EC219 !

Introduction to Systems Thinking-

Course Instructor: Jagadeesha R Bhat

Huh...Animal Abuse ...?



NOTE: *No animals were harmed during this process.*

- Credits: 3-1-0-0-4
- Pre-requisite: NIL

Description (wiki):
Systems thinking is **a way of making sense of the complexity of the world by looking at it in terms of wholes and relationships rather than by splitting it down into its parts**. It has been used as a way of exploring and developing effective action in complex contexts, enabling systems change.

Course Website

- **Class code :** aoblvmw
- **Class** Link:https://classroom.google.com/c/NTgxODUxMjYyNTE4?cjc=aoblvmw

Evaluation: (%)

- Midterm: 25
- End term: 30
- Assignments (Reading/ Writing) and Quiz: 15
- Case presentations (project): 30

- Note: Project shall be conducted in groups of 4 students. Max. (some cases 5)

Know your Teacher

- **Jagadeesha R Bhat**, PhD in CS from NTHU, Taiwan
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- Office: F320, e-Block
- Teaching (this Semester): Intro. Systems Thinking
- Contact Hours: (in class) : Mon: 1.30pm-3.00pm
- Wed: 9.00am-10.30am

  Fri: 10.45am-11.45am

For queries/ feedback: Please email me. [*Address me as: Asst. Prof. Bhat*]

Class Policies

- Class discipline (entry, exit, drinks, chit-chat, etc)
- Mobile phones and laptops (strictly no photography, A/V recording)
- Learning disabilities/ Special needs (feel free to talk to me ☺)
- Attendance policy (**85% as mandated by the institute**)
- Academic cheating (plagiarism)
- Quizzes (announced/ unannounced)

Introduction to Systems Thinking- EC219

- Everyone is involved with things called systems – information systems, financial systems, ecological systems, computer systems, education systems, etc.,

- **Systems thinking** is a holistic approach for analysis that focuses on the way that a system's constituent parts interrelate and how systems work over time and within the context of larger systems. [not a reductionist’s way]

Course Contents

- Systems Thinking: General overview, Systems thinking in practice, Ways of thinking, Types of systems, Sustainability, terminologies, iceberg model, Case studies
- Communication systems: Data (information) representations and models, components, communication over channel, Case studies.
- IT Systems: Sociotechnical nature of IT systems, Approaches to systems thinking, success in IT systems. Case studies.
- Networked systems: Design of networks using DSRP rule, tools (simulative), game theory models.
- Cyber physical systems: Cyber Physical System Introduction, CPS Applications and Systems, Real-time Scheduling with Resource-constrained Platform , Networked System Composition, Case studies.

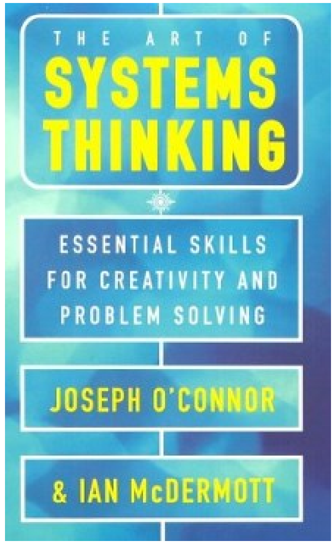
- **References**

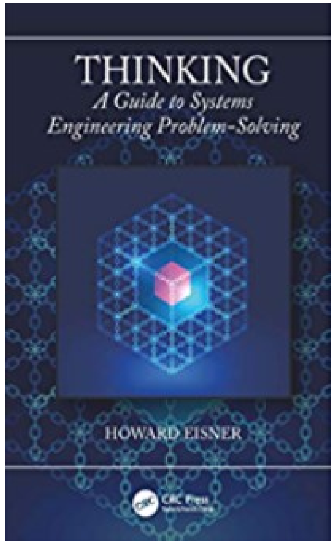
i. The art of system thinking: Joseph O' Conner & Ian McDermott

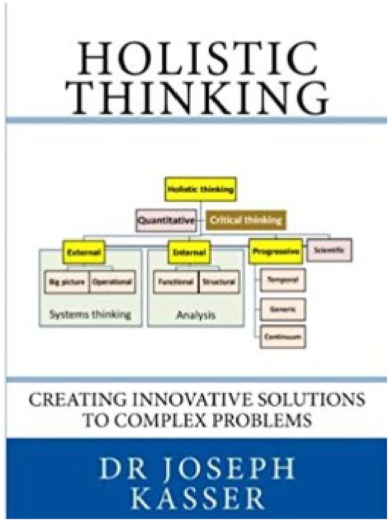
ii. Thinking: A guide to Systems Engineering Problems-Solving: Howard Eisner

iii. Holistic Thinking: Joseph E. Kasser

iv. Research Papers: will be posted in class.







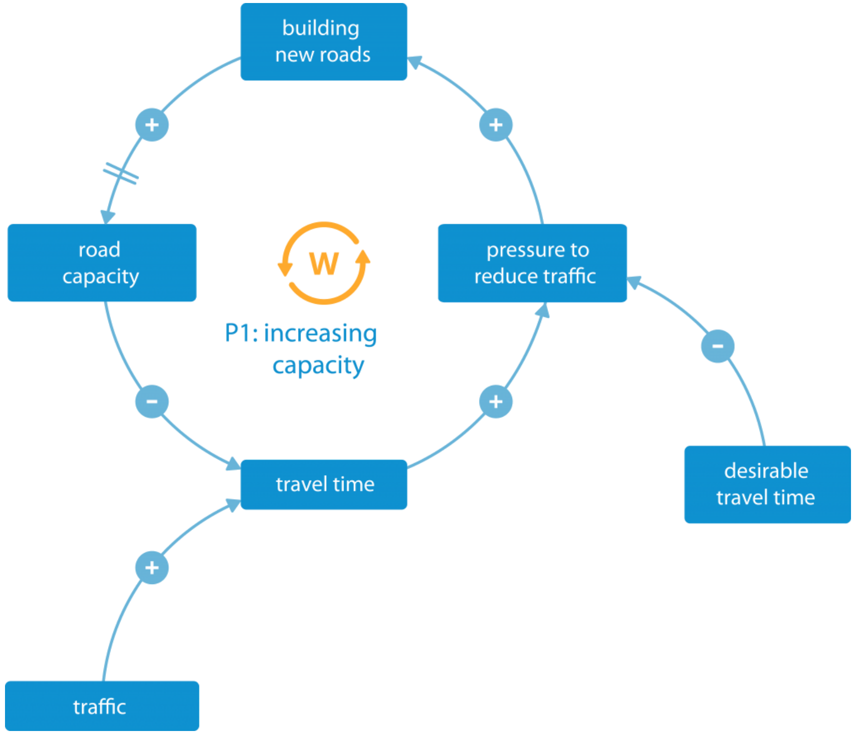
Systems Thinking

- **Systems thinking** is a *holistic approach* to analysis that focuses on the way that a system's *constituent parts interrelate* and how systems work over time and *within the context of larger systems*.
- *OR*
- Systems thinking is an understanding of how systems are **interconnected** and understanding **dynamics** within the system.

- The essence of systems thinking and practice is in 'seeing' the world in a particular way, because *how you 'see' things affects the way you approach situations* or undertake specific tasks.

- **This course will help you to learn about** the *problems of defining a system* and meet some of the key concepts used in systems theory: boundary, environment, positive and negative feedback.

- System thinking involves looking at the interconnections between parts of a whole rather than concentrating just on the parts.



- **System**: Interconnected elements that have relations and dependencies.
- *A healthcare system*

i. Elements (people, things, treatment procedures/ rules)
ii. Relationships (dependency on people,)
iii. Dynamics (changes in the system over time, how it affects relationships)
iv. Purpose (better treatment, generate revenue, etc)

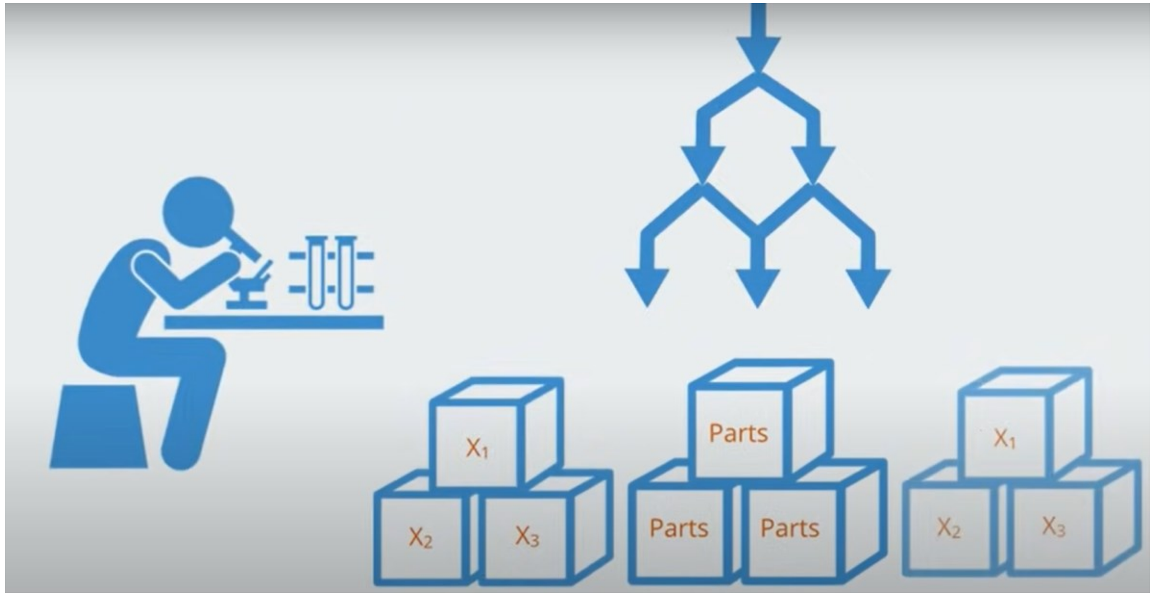
Read this case:

- A group of professionals, each given a **barometer** and asked to **find the height of a church tower**.
- The **physicist**, who remembered that air pressure changes with height, took the barometer reading at the bottom and at the top of the tower to calculate the height.
- The **engineer** dropped the barometer and timed its descent to the ground to work out the tower's height.
- The **architect** lowered the barometer on a piece of string till it touched the ground and measured the string.
- The **surveyor** measured the shadow cast by the upright barometer and by the tower and used the ratio, So found to calculate the tower's height.
- The **marketing person** went to the bell-ringer and said '*If you tell me the height of the tower, I will give you this barometer*'. [*He got it right there*]

- The story illustrates two important points –
- **first** that *people and their viewpoints are part of the situations* we normally have to deal with and
- **secondly** there is *more than one way to handle any situation*.

- Systems thinking *can help to **resolve complex situations** involving people and things, where it is as important to **focus on the relationships** between the people and things* as on the structure of a particular situation.

- Two key ways of thinking:
- **Reductionism**: actually says how those *minor components* contribute to the system performance/ behaviour. (or combination of the elements)
- **Holism**: says how a whole gets influenced by minor components with *priority to whole* (whole can not be explained by property of its parts)



Reductionism emphasizes each parts in isolation

Holistic method: understands the problem w.r.t the whole system it is a part of.

- **Systems thinking really useful** ?
- Systems thinking is important because it helps:

i. uplift natural way of thinking,

ii. providing tools for handling the complexity more adequately and

iii. helping deepen understanding; particularly regarding interactions – where we are unsure of how some things were operating and affecting the basic ‘*central*’ scenario.

- Aids reducing prejudice and helps to feel may be a more **balanced viewpoint.**

- Systems thinking allows to tackle problems not only in a scientific way but in a holistic way which demonstrates a caring approach to ***all persons at all levels connected with the problem*** or system(s) involved.

- **Systems thinking enables us to:**

Change our thinking to match the interconnected, dynamic complexity of our communities and their environments

Communicate with others to create new ways of thinking and seeing - and develop shared understanding

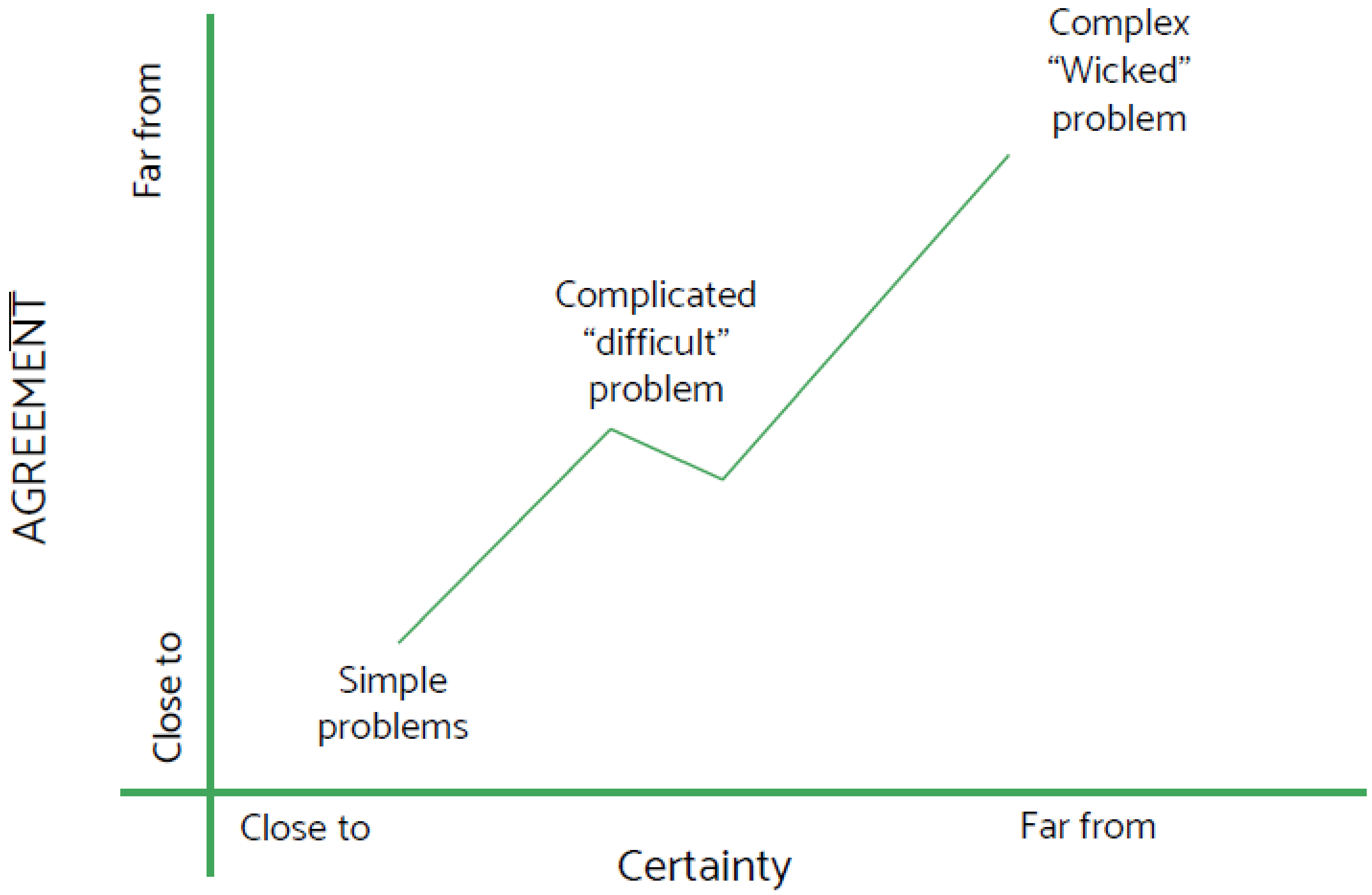
Change our behavior to work with the complex forces in the system (instead of against them) to realize our vision

Identify and test a wider variety of **possible actions and solution pathways**

Become more aware of the potential for unintended consequences of our actions

Expand the choices available to us and identify those choices where we can **develop significant leverage**

- **There are different kinds of systems**



• **Difficult problems** Vs **Wicked problems**

Characteristically smaller-scale and well-defined

- 01 Limited timescale
- 02 Priorities clear
- 03 Limited applications
- 04 Can be treated as a stand-alone matter
- 05 Limited number of people involved
- 06 Know what needs to be done
- 07 Recognisable solution

- **Wicked problems:**
- Global warming
- Traffic jams
- The Brexit

Characteristically bigger and poorly defined

- 01 Longer, uncertain timescale
- 02 Priorities called into question
- 03 Uncertain, but greater implications, worrying
- 04 Can't be disentangled from its context
- 05 Keep evolving
- 06 More people involved
- 07 No agreement on what the problem is
- 08 No 'obvious" solutions

- **Key Components: Systems Thinking**

How do the elements within the situation (components, stakeholders, knowledge, etc.) interconnect? Consequences ?

Multiple Perspectives

- World views
- Voices
- Knowledge systems

Interconnections

- Relationships
- Feedback
- Patterns

What are the different ways in which the situation can be framed or understood –by whom?

KEY SYSTEMS THINKING COMPONENTS

Define scope and scale (and from what/whose perspective is this developed.)

What drives the systems in question in particular directions (enablers, blocks, leverage points)

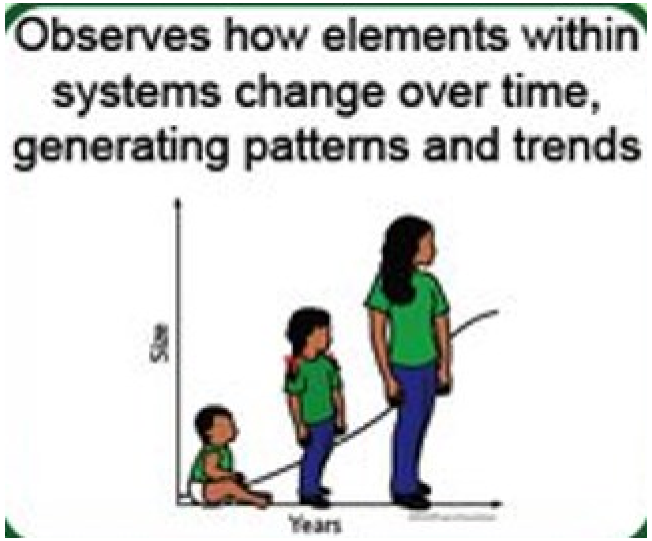
Influences

- Blocks
- Leverage points
- Drivers

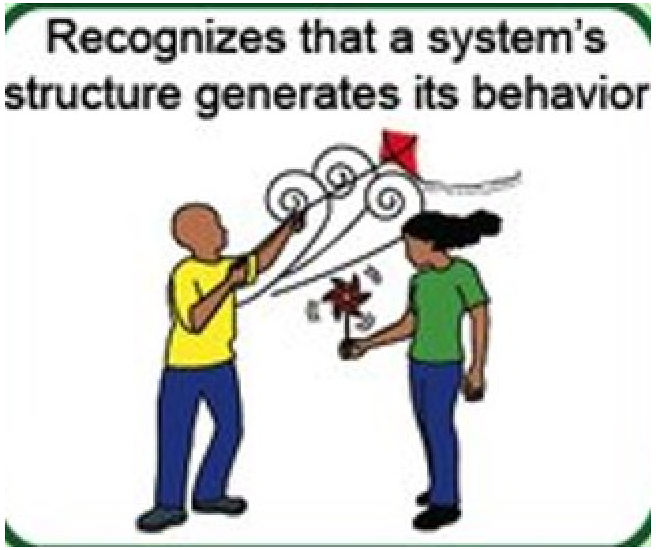
Boundaries

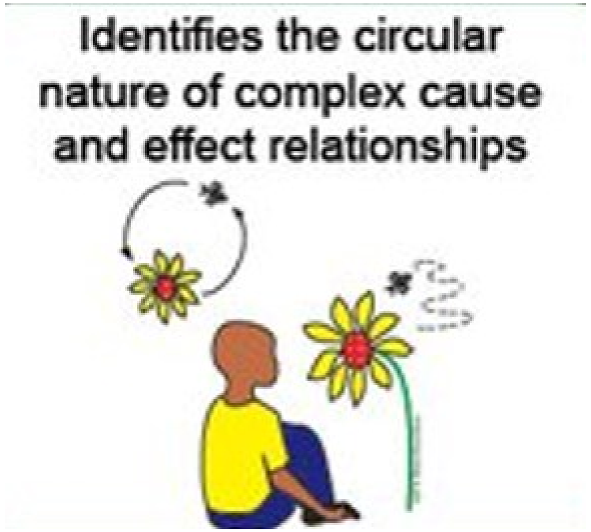
- Communities
- Systems within systems
- Scope
- Issues

- System Thinker: habits
- A system thinker will develop a spectrum of **strategies for problem-solving** and thoughtful reflection about systems of interest (as a habit).

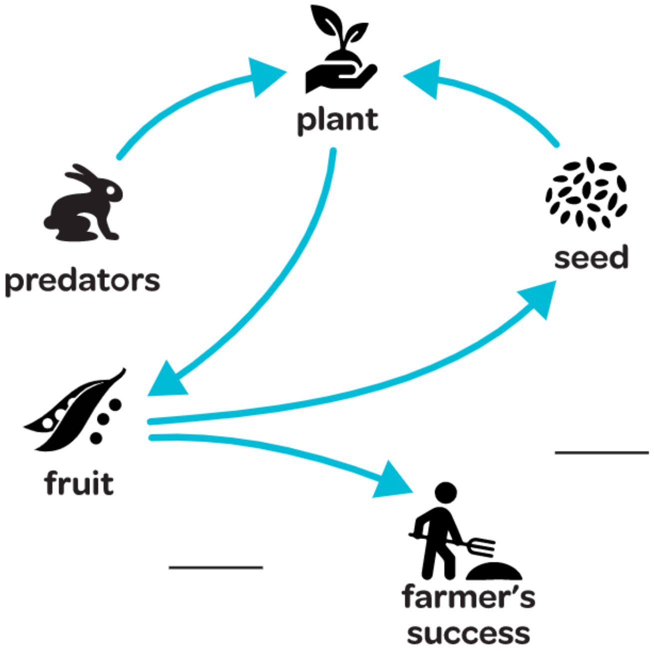


- How can I move beyond my understanding of a problem or challenge and broaden my view with the help of others in my system?
- How could their perspectives help me see challenges in ways I have never imagined?

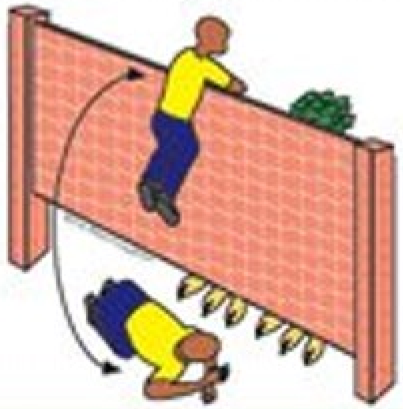

Recognizes that a system's structure generates its behavior


Identifies the circular nature of complex cause and effect relationships


Makes meaningful connections within and between systems


plant
predators
seed
fruit
farmer's success

Changes perspectives to increase understanding



Surfaces and tests assumptions

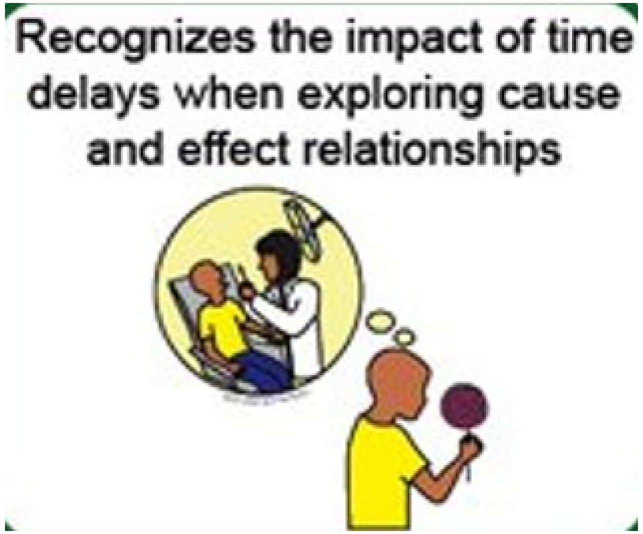
Considers an issue fully and resists the urge to come to a quick conclusion

Considers how mental models affect current reality and the future

Uses understanding of system structure to identify possible leverage actions

Considers short-term, long-term and unintended consequences of actions


Pays attention to accumulations and their rates of change


Recognizes the impact of time delays when exploring cause and effect relationships


Checks results and changes actions if needed: "successive approximation"

- **Class activity:**

- **Define a problem and identify the key characteristics that leverages it to a system thinking problem.**

- **More Ways of thinking:**
- *Logical thinking:*
- The classic example of logical thinking is a **form of reasoning** which goes like this: 'If **all cows are animals**, and **this is a cow**, then it is an animal'.
- It starts with a **generalization**, a proposition which is assumed to be true and then deduces a conclusion about a particular case.

- Logical thinking is a way of linking *ideas or statements* together.

- logic *isn't* always a good way of sorting out emotional problems, such as who to marry or whether or not to have a child.

- **Causal thinking**
- Causal reasoning is the process of **identifying causality**: the relationship between a **cause and its effect**.

- Causal thinking is a way of linking *activities or events* together.
- If A causes B, then A must put force on B which results in the effect. Cause precedes the outcome.
- Ex: The car won't start →a crack in the distributor head has caused the damp to get in which then caused a leakage of the current, which stopped the spark igniting the petrol.
- Some similarity with logical thinking (a→b). But, not totally !!

- Causality is not usually a simple matter of an isolated statement such as A-causes-B.
- You can trace causes back almost indefinitely if you want to.

$$\text{car crash} \xrightarrow[\text{caused}]{} \text{insurance claim}$$

- car crash didn't just happen spontaneously.

$$\text{driver lost control} \xrightarrow[\text{caused}]{} \text{car crash} \xrightarrow[\text{caused}]{} \text{insurance claim}$$

- Further, go deep.

$$\text{tyre burst} \longrightarrow \text{loss of control} \longrightarrow \text{car crash} \longrightarrow \text{insurance claim}$$

- Think forward

$$\longrightarrow \text{insurance claim} \longrightarrow \text{cash for holiday}$$

- **Reductionist thinking**:
- These features of looking for general principles from particular instances, ignoring subjective elements, concentrating on ‘simpler’ systems and breaking situations down into smaller parts where single cause and effects are likely, are typical of the scientific→ reductionist thinking.

- **reductionism** artificially restricts the **components** in a system to make it possible to observe repeatable experiments. ! !
- In spite of this, reductionism has proved so effective in practice and produced such outstanding results that it has become embedded in our language, literature and thought.

- **Logical and causal ways of thinking aren't so good at helping us to think about systems:**
- logical and causal thinking tries to find general principles, but we need specific solutions (system thinking for complex systems)
- logical and causal thinking → rational and objective, but we need subjective, emotional factors (some times)
- logical and causal thinking → predicts consequences, but for 'complex' systems, we cannot always predict the behaviour (any changes can lead to unintended consequences
- logical and causal thinking → cause and effect, but, systems are characterised by **interconnectedness**, and in particular by **feedback** loops.

- **Holistic** thinking:
- **Holistic** thinking deals with wholes rather than parts.

- Imagine you are trying to decide what to plant in a new garden: will you choose all plant (infinite possibilities, impossible).
- Have a view of the whole garden and decide which plants to place where (type, impact on other plants).
- **New education policy**: holistic evaluation.
- So the basic idea of holistic thinking is that you need to think about wholes rather than just about parts.
- (-) The problem with this idea is that it isn't always clear what is a whole and what is a part. (a group is a part of larger group, it's a part of small community, it's a part of larger community…so on)

- Similarly, fish→ pond→ ecology..
- Cache Memory→ processor → motherboard→ computer system
- So it looks as if, whatever you decide to think about, it is bound to be a whole !

- So, the **holistic approach** starts by looking at the nature and behaviour of the whole you are concerned with, and if this doesn't yield results, the next step will be to look at the bigger whole of which it forms a part.

- **How do you look at wholes?**

- Lets see an example: If we love someone, then all actions says that. (no matter what the receiver reciprocates, we still believe in love).
- In general, **mind believes what it feels as is correct.**
- Thus, in holistic thinking is bound **to simplify wholes**; all ways of *thinking simplify* (*familiar patterns*), because full knowledge and understanding of reality is impossible.

- One way holistic thinking simplifies things is by taking multiple partial views.

- Assume a **building**: if you **view it as slices**, you will be able to see different sections of the building. YET, they are NOT the full view of the building. *ON THE OTHERHAND*, the *slices are* NOT *wrong* !!

- The ***more slices you have the more you will know about the whole***.– they are simply more or less helpful in understanding the whole.

- With that we have a more complete definition of system thinking:

- Systems thinking can be described as 'a discipline for seeing wholes rather than parts, for seeing patterns of change rather than static snapshots, and for understanding the subtle interconnectedness that gives (living) systems their unique character' (Senge, 1990).

- **Design Thinking:**
- Assume a truck stuck under the bridge:
- Now there will be traffic congestion,
- How to solve:
- cut the bridge / dismantle the vehicle ?

- Think out of the box:-

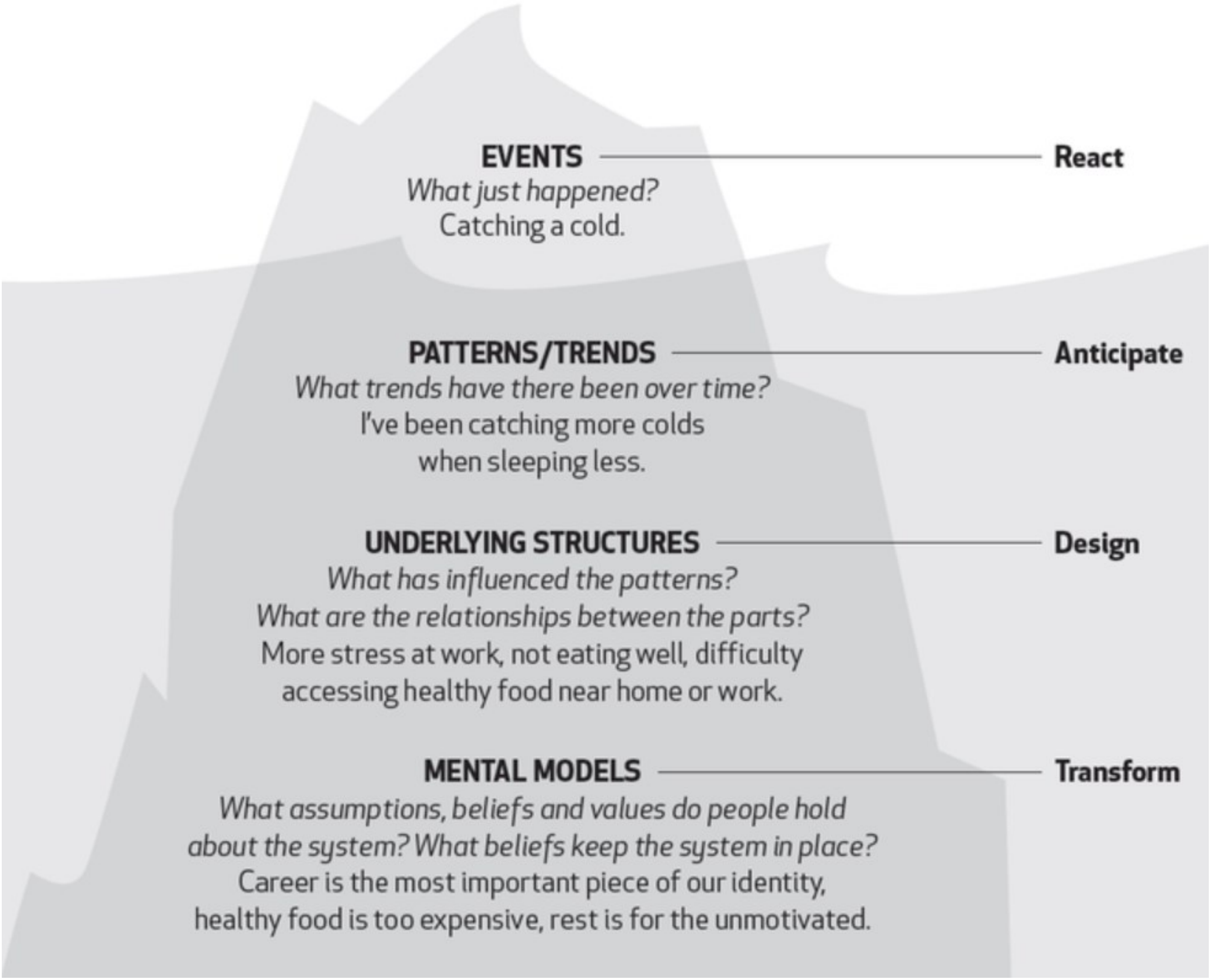
>> some one said: unblow the tyres ☺

Design Thinking divides work in different steps that focus on either divergence or convergence.

- The divergent steps orient the team towards generating a wealth of possibilities, either through research or ideation.
- The convergent steps aim to facilitate selecting among those possibilities.

- Design thinking means combining an economically viable + technologically feasible perspective that inspires empathy and understanding for your target users.
- Key *qualities of design thinking*:
- **Empathize** — with your audience
- **Define** — your insights and your audiences' needs
- **Ideate** — by challenging assumptions and developing solutions
- **Prototype** — to create these solutions
- **Test**
- The term "design thinking" now generally refers to applying a designer's sensibility and methods to problem solving, no matter what the problem is.
- An important mechanism in Design Thinking is **iteration**.

- **iceberg-model : system thinking**



- **The Event Level**
- The event level is the level at which we typically perceive the world
- the iceberg model pushes us not to assume that every issue can be solved by simply treating the symptom or adjusting at the event level.

- **Pattern Level**
- If we look just below the event level, we often notice patterns.
- Similar events have been taking place over time — we may have been catching more colds when we haven't been resting enough.
- Observing patterns allows us to forecast and forestall events.

- **Structure Level**
- When we ask, "What is causing the pattern we are observing?"→ the answer is usually some kind of structure.

- Ex: Increased stress at work/ dust exposure (for cold)

- **Mental Model Level**
- Mental models are the attitudes, beliefs, morals, expectations, and values that allow *structures to continue functioning as they are*.
- These are the beliefs that we often learn subconsciously from our society or family and are likely unaware of.
- Ex: work is important (so stress is OK), / no way to avoid dust (mask doesn't look good).

- **Class Activity 2:**
- Mention a system thinking problem and identify, explain how ice-burg model could be applied to the chosen problem.

- **Computational Thinking?**
- look for algorithmic solutions to problems, in terms of data manipulation and process control.
- Basically, computational thinking tries to apply algorithms, mathematics, logical problem solving to every instance of the scenario to be analysed (solved).

- Ex: “When your daughter goes to school in the morning, she puts in her backpack the things she needs for the day; →that’s prefetching and caching.

- “Computational thinking (CT) is a **problem-solving process** that includes (but is not limited to) the following characteristics:

i. Formulating problems in a way that enables us to use a computer and other tools to help solve them.

ii. Logically organizing and analyzing data.

iii. Representing data through abstractions such as models and simulations.

iv. Automating solutions through algorithmic thinking (a series of ordered steps).

v. Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources.

vi. Generalizing and transferring this problem solving process to a wide variety of problems.”

- **What's Wrong with Computational Thinking?**
- If computer professionals may attempt to solve all problems through algorithmic means, while failing to perceive those that cannot be expressed using the abstractions of CT.
- Problems that are unlikely to have computational solutions (e.g. ethical dilemmas, value judgements, societal change, etc) are ignored.
- Computational problems are tackled by reducing them to a set of discrete variables that can be mapped onto abstract data types, and a set of algorithmic steps for manipulating these data types.→ this ignores human nature of the problem.

- **Traffic management in a modern city offers an illustrative example.**

- Computational thinkers tend to approach traffic congestion as an optimization problem: →congestion can be reduced by optimizing traffic flow.

- Unfortunately, this solution usually has the opposite effect: congestion increases.
- This is because congestion is a non-linear property of the relationships between traffic volumes, vehicle speed, and road capacity.
- → *Spare capacity is crucial*, because it acts as a buffer during times of high traffic volume.
- ←If you optimize the traffic flow, you remove this spare capacity, and hence reduce the overall resilience of the system to small variances in demand, and a perceptible improvement in throughput tends to trigger an increase in demand anyway.

- **How could projects benefit from systems thinking?**
- At times projects executers take a linear, deterministic view of their projects using tools such as Gantt charts that string activities into a rigid sequence.

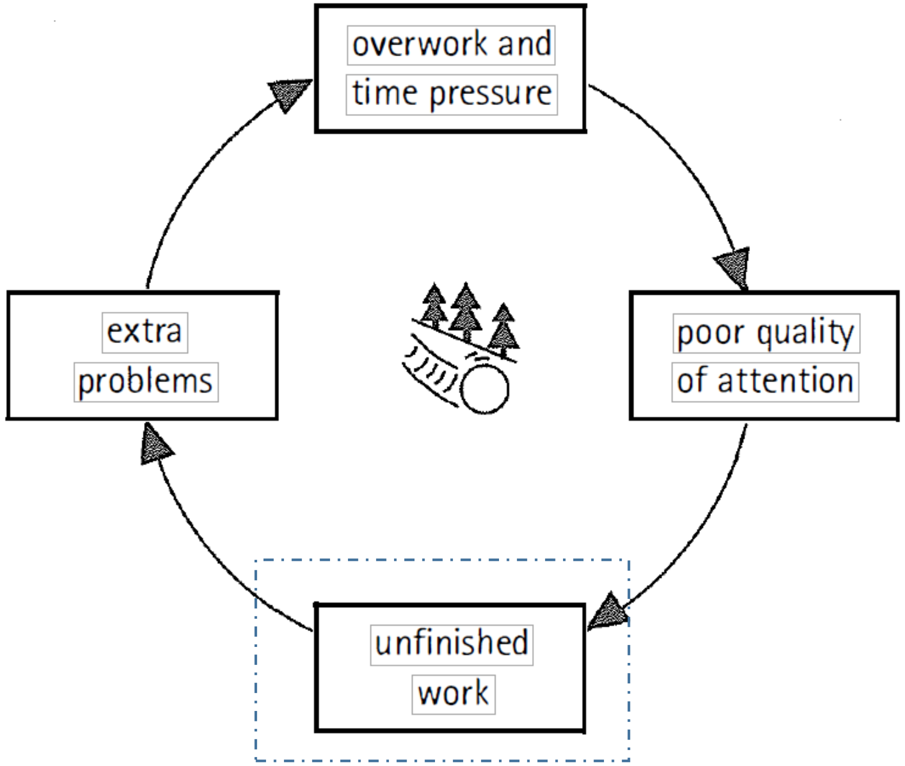
- Improve the realism of cost and schedule estimates by understanding that projects are not deterministic. [system thinking is required for determining the additional tasks (not originally expected)→ rework, halts, etc.,

- **Feedback in a system:**
- Feedback is fundamental in systems - no feedback, no system.

- **reinforcing feedback-** when the changes in the whole system feed back to *amplify the original change.*
- Reinforcing feedback drives a system ***in the way it is going*** (growth or decline)
- Reward is part of a reinforcing feedback loop if it leads to more of the same behaviour.
- Ex: Think of a snowball rolling down a hill. It collects snow as it rolls and the larger it becomes, the more snow it collects, until it eventually becomes an avalanche (down the hill).

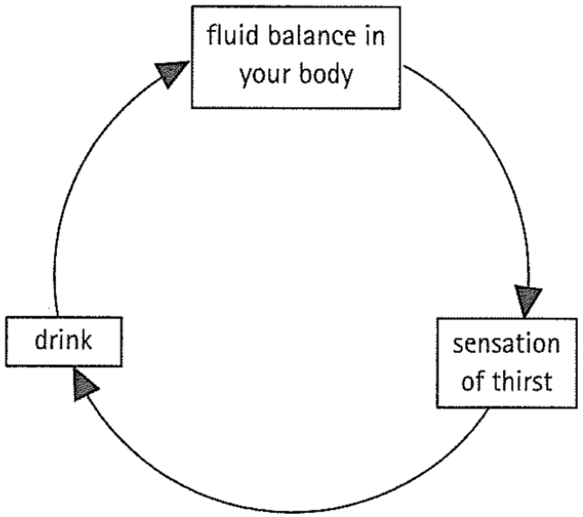
- Similarly, bank account:
- Initial investment (Rs) + Interest (reward)→ increased total (it keeps repeating every year)

- The increase shall be *linear or exponential*



- **Balancing feedback.**
- A balancing feedback loop is where change in one part of the system results in changes in the rest of the system *that restrict*, limit or *oppose the initial change*. →keep the system stable (This may help or hinder us)

- Ex: we have a body temperature. When it changes, the body generates some chemicals (reactions) to cool the body (sweat). Else we may collapse.



- Balancing feedback drives the system towards its goal - where the loop will no longer operate and the system will come to rest or be in a balanced state.

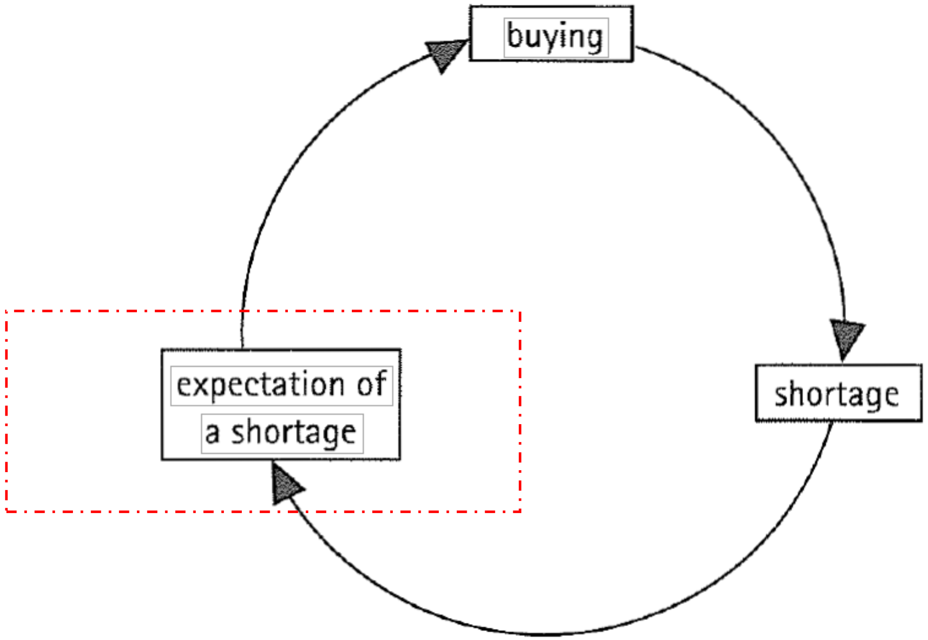
- Balancing feedback always acts to reduce the difference between where a system is and where it 'should' be.

- **Feedforward** : It comes from our ability to anticipate the future.

- It is when the *anticipated effect in the future*, which has not yet happened, *triggers the cause in the present*.→ thus the *future reaches backwards to affect the present*.

- Ex: When you expect to succeed (future), your energy and optimism (presently) **help you and make it more likely** that you will.

- When we anticipate to fail, due to anxiety we may actually fail.



- **Also read**: Rumours circulate that a particular stock will rise.
- Although the stock has not risen, these rumours attract buyers. So the **stock rises**. The more it rises, the more buyers are attracted.
- A reinforcing loop is set up.
- Eventually stock market commentators start a balancing loop by saying the stock is overvalued and it falls as people sell.

- *Occasionally* feedforward has a novel twist. The very efforts a person takes to avoid something leads to - the event happening.

- Insomnia is a slightly different example.
- Suppose you are afraid you will not be able to sleep.
- You might try to go to sleep, but the harder you try, the more difficult it becomes. The more difficult it seems, the harder you try.

- Improve the integrity and hence value of the product→ that requires anticipating possible challenges, additional tasks.

- Improve the understanding of stakeholders' needs throughout the (extended) project lifecycle. →A systems view encourages broader thinking about how a product or service meets the needs of various stakeholders.

- **Why do systems work so well?**
- Consider the properties of highly functional systems—machines or human communities or ecosystems.
- Chances are good that you may have observed one of three characteristics:

1. resilience,
2. self-organization, or
3. hierarchy.

- **Resilience** meaning : “the ability to bounce or spring back into shape, position, etc., after being pressed or stretched.

- Resilience is a measure of a system’s ability to survive and persist within a variable environment.

- Resilience is provided by several loops, operating through different mechanisms, at different time scales, and with redundancy—one kicking in if another one fails.

- **There are always limits to resilience.**
- The human body is an astonishing example of a resilient system. It tolerate wide ranges of temperature and wide variations in food supply, etc

- In human body **Self-organizing** intelligence that can learn, socialize, design technologies, and even transplant body parts. (It is resilient and has high self adaptations).

- Populations and ecosystems also have the ability to “learn” and evolve through their incredibly rich genetic variability.

- This **capacity of a system to make its own structure more complex** is called **self-organization.**

- Ex: ability of a society to take the ideas of burning coal, making steam, pumping water, and specializing labor, etc.

- Systems often have the property of self-organization—the ability to structure themselves, to create new structure, to learn, diversify, and complexify.

- In the process of creating new structures and increasing complexity, one thing that a self-organizing system often generates is **hierarchy.**

- The world, or at least the parts of it humans think they understand, is organized in subsystems aggregated into larger subsystems, aggregated into still larger subsystems.

- Corporate systems, military systems, ecological systems, economic systems, living organisms, are arranged in hierarchies.

- Complex systems can evolve from simple systems **only if** there are stable intermediate forms. The resulting complex forms will naturally be hierarchic.

- hierarchical systems reduce the amount of information that any part of the system has to keep track of.
- In hierarchical systems relationships *within* each subsystem are denser and stronger than relationships *between* subsystems.

- Feedback loops are a powerful tool in the manager's hands. The initial change in the variable (process, etc) stimulates its further change in the original direction. Thus, if we succeed in changing the variable in the direction we need (reinforcing loop), we can start the process throughout the whole context, and since the variables enter several contexts (aka contours) at once, we can launch the same series of cascade effects that will now work for us. Just remember that all systems are endowed with a balancing feedback mechanism that ensures their stability. But — in order for balancing feedback to work, measurement is necessary (i.e., to define when should we switch to balancing loop). This measurement must be accurate enough for the feedback to work adequately.

- The next time you solve a really difficult problem, try to depict cause-and-effect relationships by connecting them in loops. You may do this rather quickly or you may need a few days. Eventually, you will find that you have made a logical diagram that allows you to see the system, or at least most of it (several contexts/contours). You may want to involve the team in the discussion or to create a mental model (for example, mind map). Anyway, this diagram, even a schematic one, will be a powerful push to making the right decision.

- Mental models are cognitive representations of external reality.
- mental model: people carry in their minds a small-scale model of how the world works. These models are used to anticipate events, reason, and form explanation.