The Systems Thinking Tool Box

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".. bump, bump, bump, on the back of his head. It is, as far as he knows the only way of coming downstairs, but sometimes he feels that there really is another way, if only he could stop bumping for a moment and think of it."

Winnie the Pooh - A. A. Milne

Tree Diagram (TD) Alias Hierarchy Chart

What is it and what does it do?

Often used in conjunction with a Divergent Thinking tool, such as Brainstorming or an Affinity Diagram, a Tree Diagram is a tool that allows a team to organize a large number of ideas, opinions and issues into a meaningful structure that permits the communication their ideas in a simple but powerful hierarchical representation.

Figure 1 shows an example Tree Diagram for the breakdown of a bicycle.

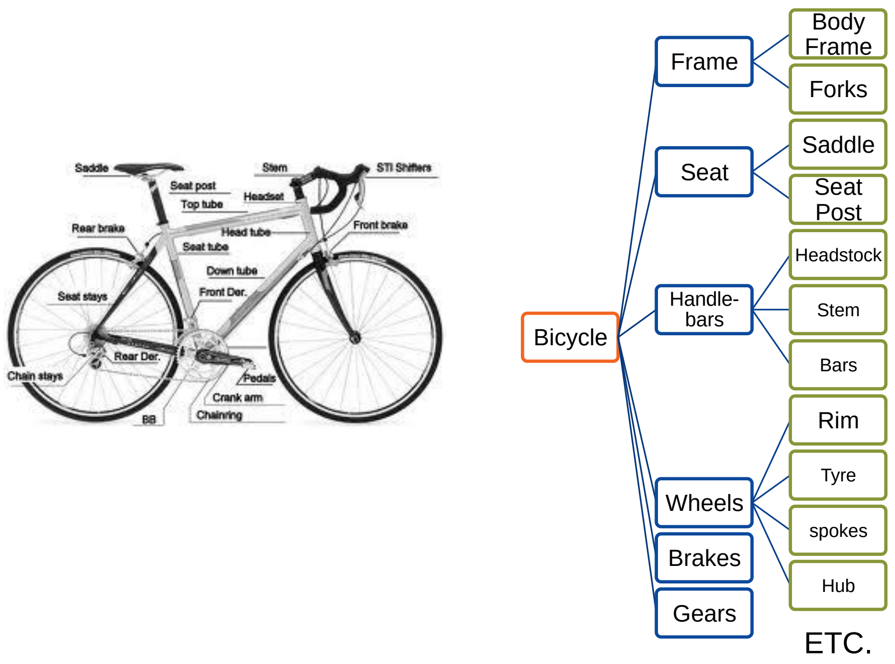

Figure 1: A Tree Diagram breakdown of the components of a bicycle

Tree Diagrams are either drawn horizontally like in Figure 1 or more commonly vertically as shown in Figure 2.

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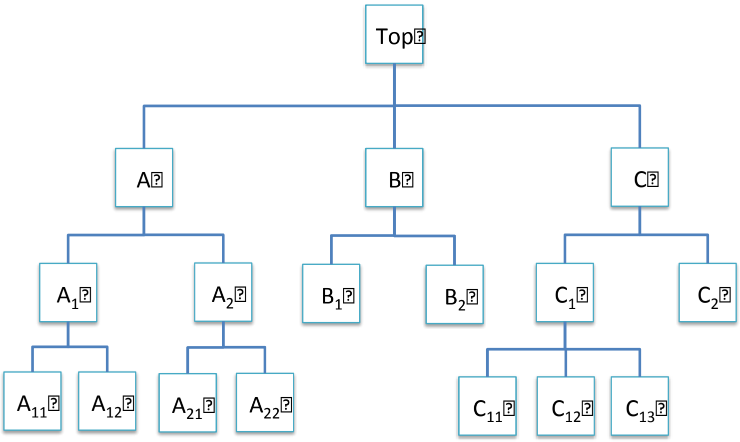


Figure 2: A Vertical Tree Diagram

Why do it?

Tree Diagrams exploit the concept of a hierarchy to manage complexity through sub-division. It is particular useful in Systems Thinking because it is a representation convention that is intuitive to most humans and therefore provides a powerful way of conveying information. The basic principle behind hierarchy is sub-division of higher or bigger "thing" into a number of lower or smaller "things". There are three basic representation conventions as shown in Table 1:

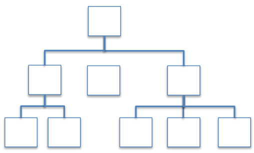
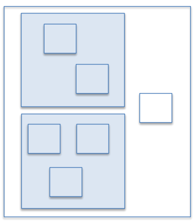
Trees	Nests	Lists
		Top item item A item A_1 item A_2 item B item C item C_1 item C_2 item C_3

Table 1: The three hierarchical representations

As is clear form Table 1, the three basic representations are interchangeable; it is a relatively trivial task to change from one representation to another. Tree Diagrams are the first, and most intuitive, form of hierarchy.

Whatever representation is adopted, there are two basic types of hierarchies:

- **Structural Hierarchies**: In structural hierarchies, complex systems are structured into their constituent parts in descending order according to structural properties such as size, shape, colour or age. For example a structural hierarchy of the universe would descend from galaxies to constellations to solar systems to planets etc. down to atoms, nuclei, protons …. down to superstrings. Structural hierarchies are intuitive to humans because they relate to physical characteristics; they align to the natural object orientation of humans.

- **Functional Hierarchies** decompose complex systems into constituent parts according to their essential relationships. For example in a washing machine all the parts relating to managing the water temperature would be structured together. Functional hierarchies logically group together parts that collectively accomplish a purpose or sub-purpose of a system. Structural hierarchies, while highly logical, are not intuitive to humans. A group of parts in a functional hierarchy will comprise parts that have different structural properties.

Systems Thinking uses both types, but Tree Diagrams are particularly useful and powerful to capture Functional Hierarchies because they are purposed based and provide a logical and rational basis for sub-division in which the relationships are essential to the operation of the system. Many Systems Thinking and Systems Engineering tools exploit Functional Hierarchies in their methodology. To name but a few; Viewpoint Analysis, Use Case Diagrams, Conceptual Models, Functional Flow Diagrams, and Sequence Diagrams all fundamentally rely on Functional Hierarchies.

In Reductionist Thinking we make more use of Structural Hierarchies because it is observable (we can see the sub-division) but the essence of the relationship between components is ignored. It is important to remember when attempting to do some Systems Thinking, a group of humans will naturally, will intuitively, resort to constructing Structural Hierarchies. In such cases the group will require strong guidance to avoid the reductionist trap.

Where and when to use it?

Tree Diagrams are used wherever we wish to manage a complex situation. They can be used to organize and manage:

- Purpose
- Goal or objective
- Task or activity
- Thing or product
- Need or requirement
- Problem or Issue

Who does it?

Tree Diagrams can be created by an individual or, more usefully, by a team. It is important that a team comprises members who have knowledge about the situation or problem. There is, however, no reason why this core team cannot be supplemented with additional members who have limited experience of the situation or problem. This can help ensure that “obvious” or “basic” information is not excluded; experts often mentally “self-censor” ideas non-experts do not.

There is great benefit in terms of quality of output and time efficiency if people, who are familiar with the tool and its use, facilitate the sessions.

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How to do it?

There are several approaches that are based upon the use of a "pre-tool" to generate the items in the tree hierarchy. These include:

- WHAT-HOW relationship
- Cause and Effect Diagram
- Affinity Diagram.

The following provides a brief summary of these approaches, but the recommended approach is via an Affinity Diagram - for which there is a full tool description.

The WHAT-HOW relationship Approach

1. Start on the left with the highest-level. WHAT. This could be a:
   - Goal or objective
   - Task or activity
   - Thing or product
   - Need or requirement
   - Problem or Issue.
2. Identify the HOWs, the next level of detail or decomposition that are needed, or needed to be undertaken, to achieve the overall WHAT.
3. For each of the lower-level HOWs, treat as a WHAT and identify at the next level down how they are composed.

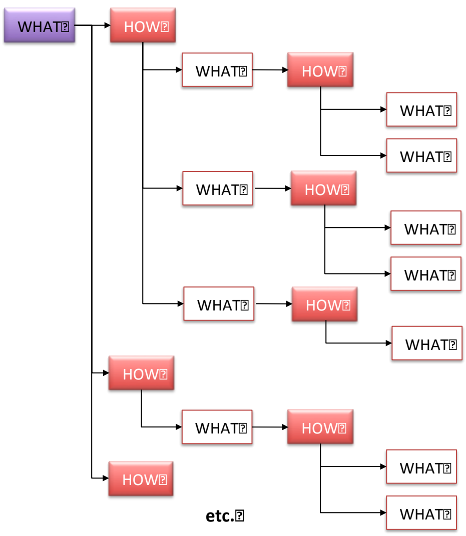

Figure 3: The WHAT-HOW Tree Diagram

While the WHAT-HOW approach can work for abstract decompositions like purpose, aims and objectives etc. It is more suited to tangible breakdowns.

It is also often necessary to iterate by moving ideas up or down the tree as their relative position is discussed.

The Cause & Effect Diagram Approach

Cause and Effect Diagram, or Ishikawa Diagram after its creator, is the classic "root cause analysis tool. Developed by Ishikawa as one of the 7 basic quality tools[1] to help members of a *Quality Circle* undertake local improvement activities. Figure 4 shows a Cause and Effect Diagram the out from the analysis of "long queues" in a cafeteria.

[1] The 7 tools are: Cause and Effect Diagram, Check Sheet, Control Chart, Histogram, Pareto Chart, Scatter Diagram and Stratification Chart.

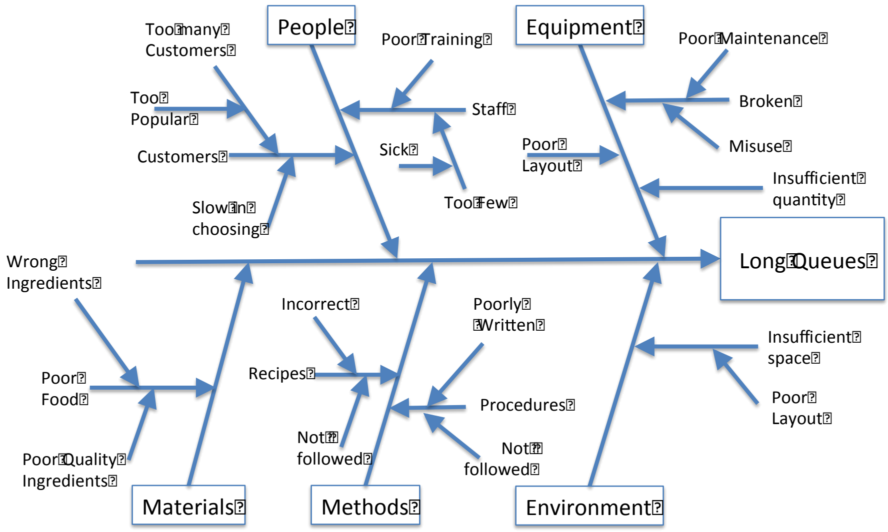

Figure 4: A Cause and Effect Diagram for "long queues' in a Cafeteria

Figure 4 is a classic use case for Cause and Effect Analysis, where a small team of "improvement agents" tackles a local problem and uses the tool to identify and organize potential causes. While Cause and Effect Diagrams are relatively simple, to the uninitiated they can at first appear complex and confusing. However, Cause and Diagrams have a simple relationship with the very intuitive representation by means of a simple hierarchy. In other words, it is quite straightforward to convert a Cause and Effect Diagram into a Tree Diagram as shown in Figure 5.

In Figure 5 the root of the Tree Diagram is the Observed Effect and the branches are the various causes, sub-causes, sub-sub-causes etc. that make up the Cause and Effect Diagram.

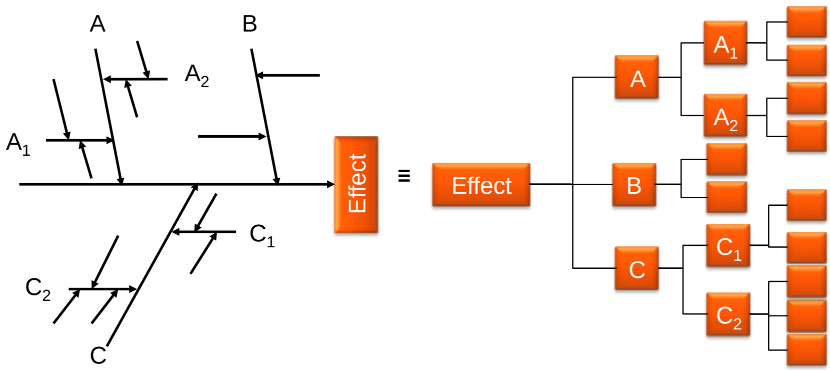

Figure 5: The structural equivalence between Cause and Effect Diagrams and Tree Diagrams

The Affinity Diagram relationship Approach

Affinity Diagram is one of, if not the, most powerful Divergent – Convergent Thinking tools. They do suffer, however, from an output that is not intuitive to the novice. To overcome this issue a common approach is to convert the Affinity Diagram to a Tree Diagram.

In simple terms, an Affinity Diagram is a brainstorm of ideas about a situation on to sticky notes which are then arranged into named themed groups The themed groups can be further sub-divided to bring out any natural structure. One of the strengths of Affinity Diagrams is that the various groups can overlap allowing an idea to reside in several groups. This is illustrated in Figure 6 which shows and Affinity Diagram for the requirements of a washing machine.

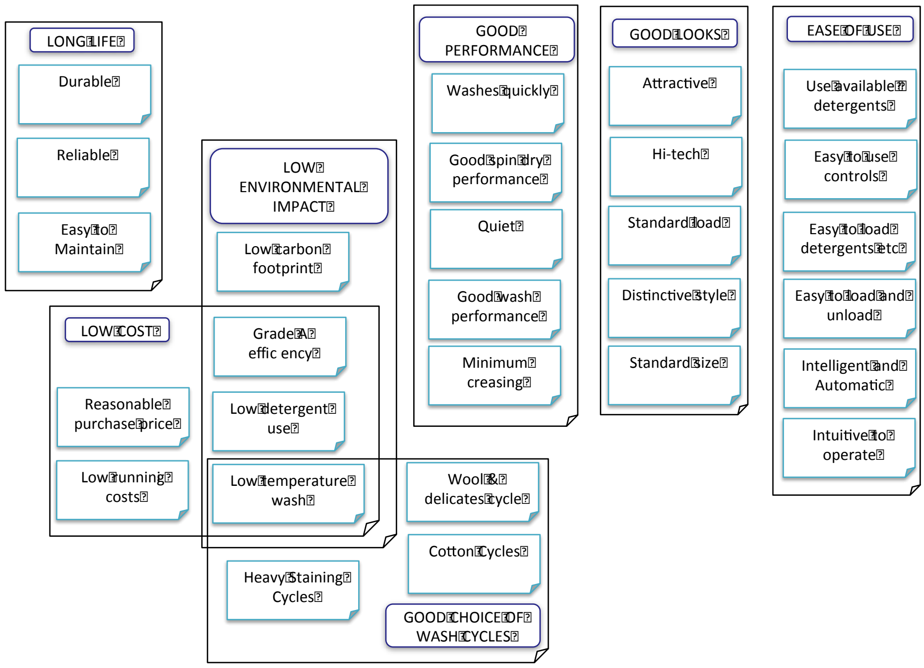

Figure 6: Nested Affinity Diagram of the Requirements for a Washing Machine

Note, in Figure 6, the requirement for a "Low temperature wash" resides in the "Low Cost", "Low Environmental Impact" and "Good Choice of Wash Cycles" groups.

Affinity Diagrams are a very powerful representational tool that allows complex relationships between items to be simply portrayed. They are, however, not intuitive to read when first encountered. Novices often misinterpret the diagrams or ignore them since their message is not apparent. This can be a critical failing of the diagramming method since one of its prime purposes is to communicate the ideas of a team or individual. Indeed, it is critical to good Systems Thinking and Engineering that ideas and thoughts are clearly communicated for review in order to test for completeness and correctness. If the reviewing audience is not familiar with the Affinity Diagram representation then the ability to test completeness and correctness is reduced. However, Affinity Diagrams have a simple relationship with the very intuitive representation by means of a simple hierarchy. In other words it is quite straightforward to convert an Affinity Diagram into a Tree Diagram as shown in Figure 8.

In Figure 7 the main group headings become the first level of the hierarchy. Sub-group headings become the next level and so on until the lowest level captures the individual sticky notes.

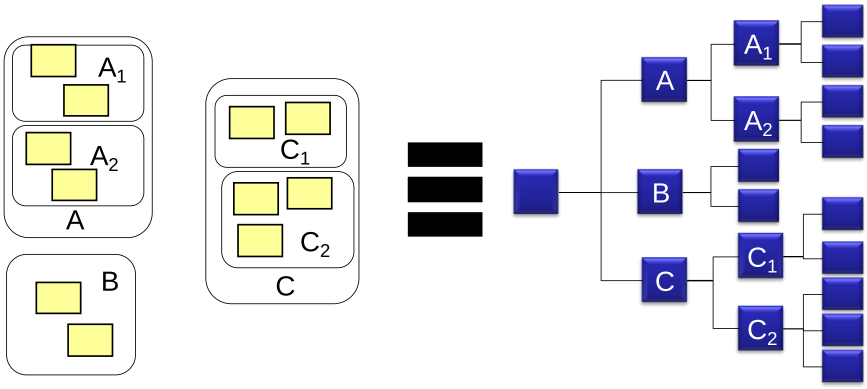

Figure 7: The structural equivalence between Affinity Diagrams and Tree Diagrams

To complete the washing machine requirements example, Figure 8 shows the Tree Diagram equivalent to the Affinity Diagram shown in Figure 6. Note how the overlapping groups of the Affinity Diagram are captured in the Tree Diagram through multiple connections.

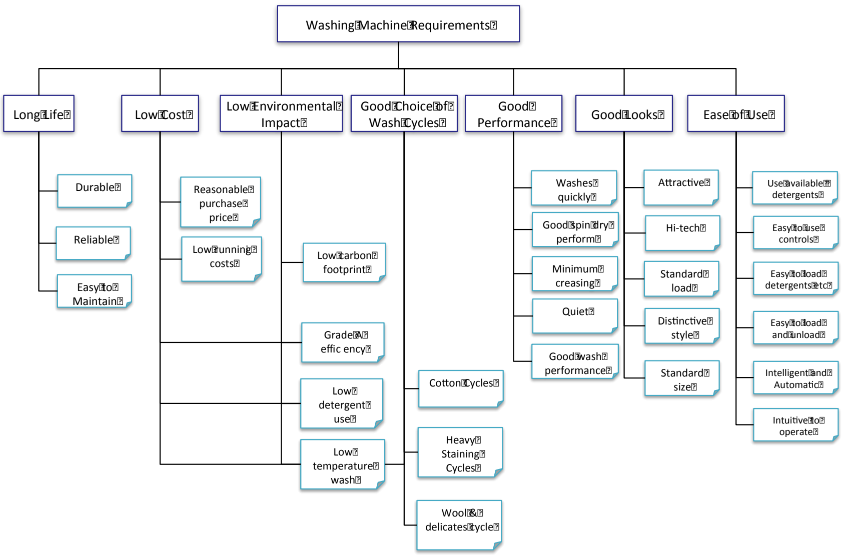

Figure 8: Tree Diagram representation of the washing machine requirements

What Goes Wrong: The limitations of Tree Diagrams

Tree Diagrams are a very simple tool for representing information and ideas in a naturally intuitive format. It does however have limitations and can be awkward to use. Some of the issues with its use are given below with advice on avoiding, and recovering from, the problem:

- Individuals dominating the grouping. If the group is hierarchical consider using a facilitator or limit the number people involved in the grouping
- Tree Diagrams do encourage Reductionist Thinking. Using an Affinity Diagram to generate the groups can discourage this.

- Often find levels of generality misaligned with the tree hierarchy. In other words detailed components too high in the tree structure. Should always review the Tree Diagram for alternative groupings

Success Criteria

The following list represents a set of criteria that have been found to be useful when constructing a Tree Diagram. Ignore them at your peril!

- Team size between three and six.
- Team constitution covers system life cycle and potential technology.
- Use an experienced independent facilitator, particularly when attempting to combine individual's efforts.
- If using an Affinity Diagram to generate ideas:
    - check out duplication fully.
    - Headers need to reflect the context of the diagram. e.g. If using to generate requirements, headers must be requirements etc.
- Three levels of hierarchy are usually sufficient. If more is needed consider a series of top-down Tree Diagrams.
- Keep the structure simple – consider different groupings.
- At each level/group go for seven or fewer components.