

# 1 Analytical invention

When we started to write this book, we began in the deep theory, but on reviewing it concluded that it would be more helpful to begin with something more immediately useful. If you read no further than this chapter and then go and apply the methods described here, you should be able to invent with the same approach as many great engineers and inventors of the past (although we hope you read on, of course, increasing your skills still further).

There is a whole range of approaches that can be used to create new ideas, from a structured, analytical approach to softer, more conceptual methods. For many inventions, the analytical methods, though simple, are very effective and this is where we will start.

The basis of analytical invention is very simple. First, you decompose, breaking things down into manageable pieces, and then you and examine, question and consequently improve the individual parts.

## Decomposition

A standard scientific and engineering approach to problems is to decompose the item in question into smaller elements which can be dealt with on an individual basis. This general principle gives rise to a number of methods which are described in the following sections.

## Chunking

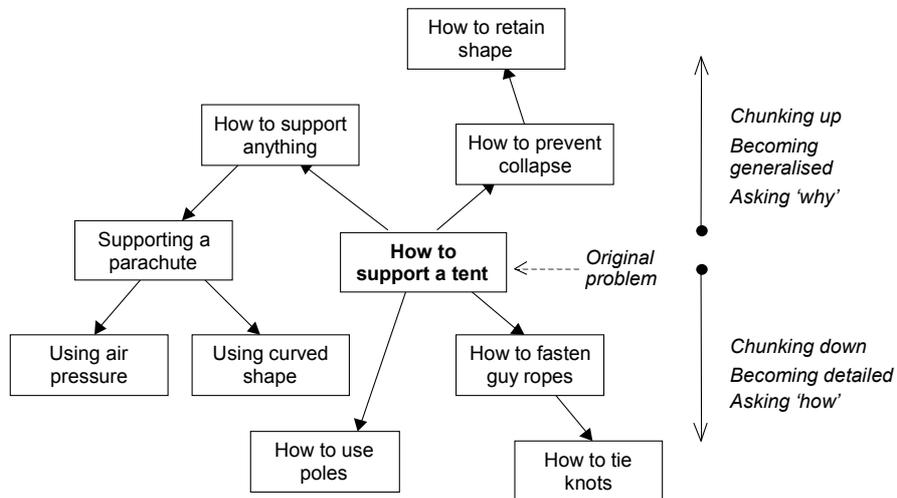
The brain understands things in distinct chunks (see Chapter 7), building large chunks out of smaller chunks. Thus a tree is made from leaves, twigs and branches. We can use this principle of hierarchical analysis to understand many inventive situations.

The simplest method of chunking is to break things down into their individual parts, thus a keyboard may be broken down into keys, casing and connector, with the connector breaking down into sheath, screw and pin assembly, and so on. The inventive eye can then be focused on very specific aspects, such as the force required to push the pins into the sockets or the ease with which the connector casing can be grasped.

We can also chunk up, looking at the big picture. This is particularly useful in the early stages of invention when you are asking questions like, ‘What is the *real* problem here?’ As you chunk up further, you will get to more general, broader areas. You can also then chunk back down through different branches to discover new areas of focus. For example, in Figure 1.1, we chunk up from supporting a tent to the general problem of support, and then back down to specific alternative ways of providing support.

A trick of chunking is in the questions you ask as you chunk up or down. By changing the questions, you will discover different things. A simple alternative is shown in Figure 1.1, where you chunk down by asking ‘how’ and chunk up by asking ‘why’. You could also ask ‘What is the benefit of doing this?’ to chunk down, and ‘What problems are solved by doing this?’ to chunk up.

Chunking is a valuable technique around social or other intangible areas where you can get into more detail by asking such questions as ‘What, specifically?’ or ‘How does that happen?’ Thus Federal Express found its famous ‘hub and spokes’ strategy by chunking up to look at the bigger picture and the overall purpose then finding an alternative approach, followed by chunking down into the details of how this might work.



**Fig. 1.1 Chunking**

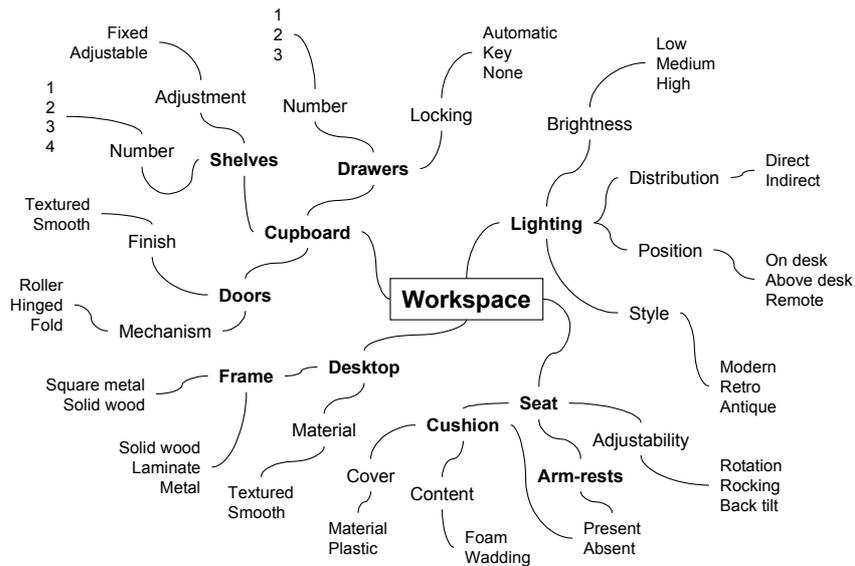
### Attribute analysis

If you are looking at a chair and have chunked down to the legs, the next level of detail may be found by examining the *attributes* of the chair legs. These may include simple, measurable factors such as length, thickness and density. More complex attributes may also be considered, such as shape, connection method and load-bearing characteristics. You could even look at the aesthetic attributes, including texture, colour and attractiveness.

When you have identified attributes of interest, you can then find the values that the attributes can have, and then decide how you might change these. Some can be changed continuously, such as the thickness of a chair leg, while others are changed in discrete chunks, such as the use of either hardwood or metal for the legs.

When you are inventing for a particular marketplace, attribute analysis can be used in combination with other techniques, such as customer needs analysis, to discover which attributes are particularly important (and hence where people would be prepared pay more).

Figure 1.2 shows how you can break down a problem area into parts, attributes and potential values which you can then change.

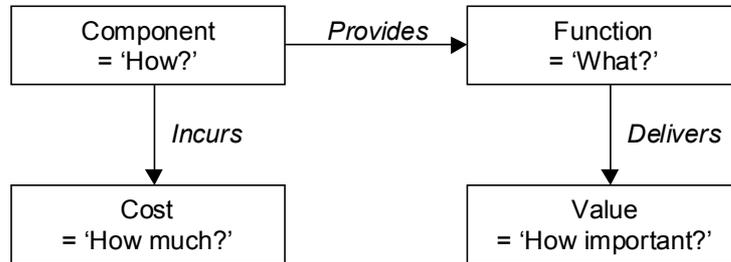


**Fig. 1.2 Breakdown to find attributes and values**

Service industries have many intangible attributes, and similarly, this is virtually all that you have with which to invent. Deliveries have timescales and reliability, customers have satisfaction and loyalty, processes have cost and capability.

### Value analysis

Value analysis is an established part of the discipline of value engineering that is founded on the principle that when you use or make something, it should add clear value, and that the value created should be greater than the cost incurred. As Figure 1.3 indicates, this can be done through identifying components and their cost, then comparing this with the functions they perform and the value thus created. For example, a volume control on a radio performs the function of changing the level of sound. Although quite cheap, it adds useful value.



**Fig. 1.3 Decrease the cost or increase the value**

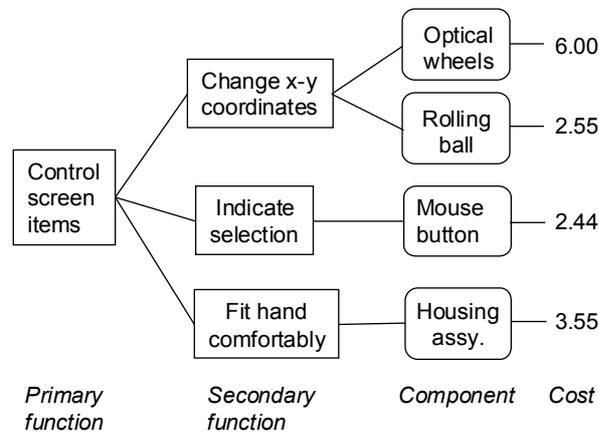
The general principle of value is a simple ‘return on investment’ idea. People will spend money on things that they think are worth it. These ‘people’ include those who invest in the company (and to whom lower production cost is of value) and end customers, to whom functions of the product or service you offer provide distinct value.

The first step of value analysis of any given component is to identify the primary functions of a selected component. These may be either *use* or *aesthetic* functions and can often be identified by asking questions such as ‘What is the customer actually paying for?’ For example, a coat may have a use function of ‘keep me warm’ and an aesthetic function of ‘make me look attractive’.

Secondary functions may then be discovered which support the primary functions. For example, secondary functions that support the ‘attractive’ aesthetic function may include shape, colour and so on.

Further breakdown can then reveal the parts of the product, the processes that create them and the costs incurred in each, consequently enabling you to question and improve any of these, as in Figure 1.4.

Value analysis aims to make visible that which is often intangible, which makes it a very useful technique for use in service and other people-oriented situations where value is particularly key and aesthetic functions may be as important as use functions.



**Fig. 1.4 Partial functional breakdown of computer mouse**

## Questioning

Once a problem situation has been decomposed into various constituent elements, questioning provides a way of discovering and challenging the deeper and unwritten detail. Questioning is also useful before or without decomposition, to expose assumptions and elements that have not been considered.

### Purpose analysis

A good question to ask when investigating a device or system is ‘What is it for? What function does it perform?’ This may seem an easy question but it can be surprisingly difficult to answer.

For example, if we ask ‘What is the function of a light switch?’ you might answer ‘To turn the light on and off.’ But this does not really give much of a clue to enable a creative focus to be put on improving the light switch. We could chunk in and answer ‘to make an electrical connection’ which might lead us to electronic switching. We can also ask more radical questions such as ‘What if we did not have a light switch, leaving the light permanently on?’ It would run up the electricity bill, so an alternative purpose might be ‘To save electricity’. This could lead us towards dimmers or people

detectors that automatically turn off the lights when nobody is there (who needs a switch?).

We can also ask the question ‘Why?’ when inventing around intangible situations, where the lack of a physical item can make the original purpose even more difficult to identify. What is the most fundamental purpose of the fire service, business consultancies or journalism?

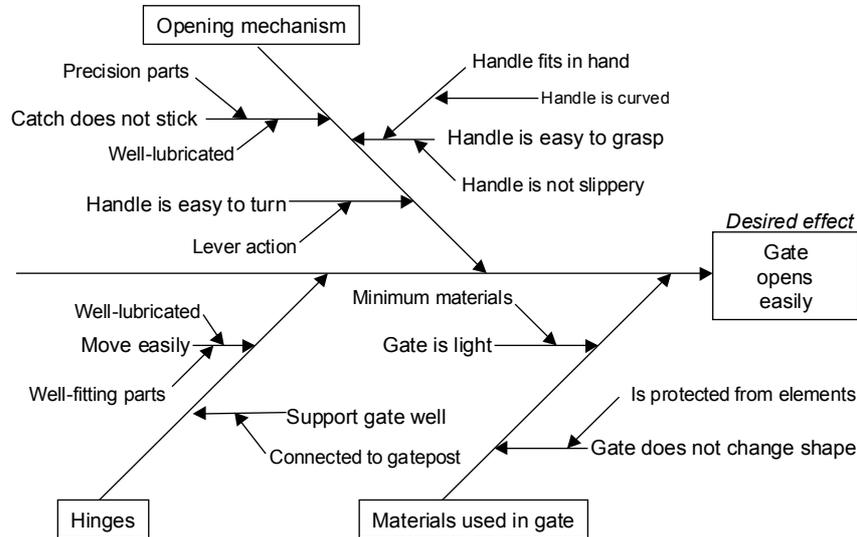
### **Causal breakdown and the cause-effect diagram**

The most basic questions that can be asked around inventions are those often asked by children. ‘Why does that happen?’ investigates causes (we are particularly interested in causes because it allows us to forecast the future). If we ask ‘How can we do this?’ we are also investigating cause: we now want to know *how to cause* something.

Many inventions are around causality. For example, the umbrella causes rain to be deflected from the person underneath. It also has undesirable effects, for example causing the person holding the umbrella to have tired arms, or that the ribs of the umbrella strike and hurt people nearby. By understanding causes, we can invent ways to cause desirable effects and prevent undesirable effects (and it can be argued that this is all that invention is about).

A simple method of drawing out causes is the cause-effect diagram, also known as the Ishikawa diagram (after its inventor) or the fishbone diagram. In essence, it simply involves chunking down, not into parts but into causes. The desired or undesired effect is placed in a box to the right, major aspects of the situation form the major ‘ribs’, then causes are added by asking ‘How or why might that happen?’ You can then select one or more causes on which to work (see Figure 1.5).

In the intangible area of social invention a cause-effect diagram for investigating the breakdown of marriages might have areas such as ‘relatives’, ‘work’ and ‘relationship’ and could lead to such ideas as whole-family counselling or spouse-days at work.



**Fig. 1.5 Cause-effect diagram for desired cause**

### Root cause analysis/Five whys

When seeking causes of a problem, addressing the first cause you find does not necessarily lead to an effective solution. For example, when a medical plaster does not stick well to skin, asking ‘why’ may reveal that the adhesive does not bond well to sweaty skin. Telling people to dry their skin will work, but it will not lead to an invention for plasters that stick even to damp skin. To do this requires a deeper understanding of causes.

If you have young children, you will know that when they repeatedly ask you ‘why’, they can force you to think about real detail. In root cause analysis, we keep asking ‘why’ or otherwise seeking causes of causes to get to the heart of the true problem, so we are addressing the real cause, not just a symptom. If you do this five times (hence the name ‘five whys’) you will very likely get to the root cause along the way. Chaining arrows, as in the cause-effect diagram, can be a useful way of making these relationships visible.

## Causal chains: sequences of events

Causes do not always work in hierarchies and sometimes it is more useful to explore how things cause one another in chains and loops. Notice how Figure 1.6 tells the story of the thinking around the problem: for a rigid gate, we could use metal, but that is heavy, so what if we put holes in it? Wire mesh is too floppy. Wrought iron would do this, but it is high cost. However, we could achieve the rigidity with a simple metal frame, with a plastic imitation 'wrought iron' effect.

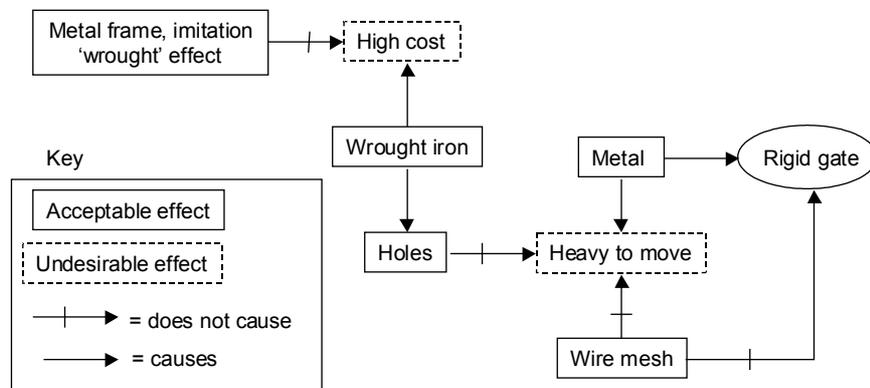


Fig. 1.6 Causal chain

Beyond causes, we can use further questioning to identify alternative solutions to our problems.

## Critical thinking

Critical thinking is a general school of thinking that goes back to Socrates, Thomas Aquinas and Descartes. Its basic tenet is to think rigorously about any given topic (and its dread enemy is sloppy thinking).

To use critical thinking, consider the clarity, accuracy, relevance, depth, breadth and rationality of any arguments. Also understand the different viewpoints that may be taken, and how each may result in a different interpretation, based on different assumptions, concepts, goals and other information.

With critical thinking, you should discover and challenge all suppositions and test all arguments and conclusions. You should thus ‘leave no stone unturned’. The inner critic that can be an enemy of a ‘soft creative type’ is the friend and mentor of the critical thinker (which is a strange paradox, as both can come up with creative and practical ideas).

Some of the questions you can ask in critical thinking include:

- What is your objective? What are you really trying to achieve?
- From what viewpoint are you considering the situation?
- On what information are you basing decisions? Where did this information come from?
- How clearly factual is the information? All of it?
- How logically are you analysing and arguing?
- What are the scientific bases? How soundly are they proven?
- What concepts are you using? How valid are they?
- What are the underlying assumptions? What are the implications of using them?

### **Bionics (also called biomimetics or biomechanics)**

Nature has already solved a lot of problems through years of evolution and you can steal from this hoard of inventions by finding the principle behind your problem then asking where and how nature might have solved it. For example, solve optical problems by looking at the eye; for camouflage look at the colouring of many animals; if you have a cooling problem, look at rabbit’s ears or sweat glands.

Nature has also solved many social problems – just look at the number of marital arrangements out there, ranging from lions with a single male and many working females, to spiders where the male ‘coming for dinner’ has a whole new meaning. Whatever your problem, try asking ‘What natural situations are like this?’ and ‘How has nature solved this?’

### **Constraints of invention**

When both nature and people are inventing, we each need to make something which *works*, resulting in a form which fulfils a useful purpose. Buildings and other structures should withstand the weather and other external forces on them. There should be enough energy to complete the task.

However, there are always constraints. Nature has an amazing range of materials available and medicines are still being created from newly discovered Amazonian plants, but it is still constrained in the biological formation of fibrous and calciferous materials. Our harnessing of energy has allowed us to smelt metals, crack oil and otherwise generate a staggering number of materials, all with different and interesting properties that we can use in our inventions, but we still have constraints.

Human invention constraints are often around cost, either direct material cost or around factors such as time and ease of manufacture. Nature has, literally, all the time in the world; we are constrained by market windows. Nature's factories are biological and growth-oriented, resulting in irregular shapes. Ours are mostly constrained by machines and assembly, resulting in rigid, regular shapes. Financial cost is a human invention: nature's costs are only in the trade-offs between big and small, hard or soft.

One of our challenges, then, is to extend our invention skills to reducing time, costs and manufacturing methods. We can use nature as a source of inspiration, but also must recognise that it also has constraints, and when we copy it, we should seek only what it can give, and not be held back by its limitations.

## 5W1H

A simple set of questions that may be used in many circumstances is: Why? What? Where? When? Who? How? This may seem trivial, but they can be very powerful in the right hands. For example, if designing a new style of bookcase, ask:

- Why is it needed? To keep books upright.
- What does it do? Apply pressure to sides of books.
- Where is the pressure applied? *To end books only.*
- When is pressure applied? *When the bookshelf is full.*
- How can pressure be applied all of the time? *With long-travel, spring-loaded book ends.*
- Who can make these? A spring-design company. There is one down the road.

## SCAMPER

This acronym comes from a revision by Robert Eberle in 1972 of a list drawn up by brainstorming originator Alex Osborn to help stimulate new ideas. The letters stand for:

- Substitute?
- Combine?
- Adapt?
- Modify?
- Put to other uses?
- Eliminate?
- Rearrange?

You can substitute for such things as people, places, units, materials, processes, methods or purposes. For example, if you wanted to improve on a bicycle seat, you could substitute foam for the springs or rain-resistant materials for the seat fabric.

Combinations of people, places, units, materials, processes, methods or purposes can be used. Maybe the bicycle seat could be combined with the pedals, so rocking of the body contributes to forward motion.

In adaptation you can copy from other ideas, nature, people or principles. Perhaps you could adapt an armchair for the bicycle so you could ride in comfort.

Modification can change size, speed, frequency, smell, position, weight, number or any other variable. You can magnify to see the detail or enlarge, or minify to reduce, streamline or make small. Perhaps with a minimal seat, the bicycle rider would suffer less chafing of the thighs.

You can eliminate parts of the problem or the solution, time, effort, costs. What if there was no bicycle seat? For a sprint-racing cycle, this could save weight. If the seat were a part of the frame, you could eliminate manufacturing time and cost.

Rearrangement can be done with parts and patterns, time sequence or speed. Perhaps you put the seat on yourself before you get on the bicycle, incorporating a snugly fitting seat into a pair of racing shorts.

You can combine any or all of these. For example, when redesigning a lighting display, you could:

- Substitute glass with plastic
- Combine the socket with the filter
- Adapt it to fit a range of fluorescent lamps
- Modify the shape to expand with lamp length
- Put the lamp to another use, such as providing local heating
- Eliminate visible cabling
- Rearrange the layout to fit the switch into a hidden handle.

## **Verbs**

SCAMPER is only a small set of ways to change things. You can easily find other ways to change, by selecting any number of verbs which modify the problem in some way. You can stretch, heat, melt, grate, cut, erode, show, hide, shake, flatten, grind, carve, compress, simplify, reduce, revise, attack, paint, smell, soften, wrap, throw, etc.

Taking one of these, say 'reduce', and a problem such as 'how to stop my coffee from spilling', could lead to a cup with a reduced opening or putting less coffee in the mug.

SCAMPER and verb modifiers can also be applied to intangible invention. For example, Dell's strategic invention of selling computers direct to the public could have been found by using the 'Eliminate' question on a picture of the standard industry supply-chain process.